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BRICK ROADS.[1]

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INTRODUCTION.

A clay product closely resembling our present-day brick was among the earliest materials used for paving streets and roads. The first brick pavement constructed in this country, however, dates back no further than 1872, and to Charleston, W. Va., belongs the distinction of having been the first American city to employ brick for paving.

For a number of years after being introduced into this country the use of paving brick was principally confined to city streets, and, owing to the frequent inferiority in the quality of the brick and lack of care in construction, very few of the early pavements proved satisfactory. Even now, after the experience of 40 years has demonstrated that it is entirely practicable to construct satisfactory brick pavements when proper care is exercised, and that much waste results from the use of poor materials or faulty construction, instances can frequently be found where comparatively new brick pavements have wholly or partially failed from causes which might easily have been prevented. (See Pl. I and Pl. II.)

Country roads paved with vitrified brick are becoming quite common in many of our States. The principal advantages which brick

[1] A revision of Department Bulletin 246, entitled "Vitrified Brick Pavements for Country Roads."

roads possess may be stated briefly, as follows: (1) They are durable under practically all traffic conditions; (2) they afford easy traction and moderately good foothold for horses; and (3) they are easily maintained and kept clean.

The principal disadvantage is the high first cost. The defects which frequently result from lack of uniformity in the quality of the brick or from poor construction are usually to be traced indirectly to an effort to reduce the first cost or to a popular feeling that local materials should be used, even when of inferior quality.

This bulletin purposes to furnish information relating to the construction of brick roads and to supply suggestions for aiding engineers in preparing specifications under which such work may be satisfactorily performed. One of the most essential features of the construction of brick pavements is the selection of the brick, since the success or failure of such pavements depends to a large extent on the character of the material used. In order that the significance of the varying physical characteristics observed in brick manufactured under different conditions may be more readily understood, a brief discussion of the raw materials and processes used in the manufacture of brick will be given.

THE RAW MATERIALS.

Paving brick are made from shales and fire clays. The "lean or less refractory varieties of these materials, which are found in the carboniferous deposits broadly distributed throughout the United States, are best adapted for this purpose.

Shales frequently occur in such quantity and are so located that they may be readily excavated by means of a steam shovel or other mechanical device. Occasionally the deposits are comparatively thin and underlie other material, making it necessary that they be mined. Fire clays are usually found interstratified with coal deposits which may or may not be workable, and must, therefore, generally be mined. The principal difference between fire clays and shales, in so far as the manufacture of brick is concerned, is essentially a difference of color in the finished product. The shales always contain iron in some form, and brick made of shale are usually red. Fire clays are free from iron and should produce a light-colored brick. Some low-grade fire clays, however, may be darkened by certain firing conditions too complicated to be discussed in detail here.

Shales and fire clays as they occur in nature are not always well suited for use in the manufacture of paving brick, but must frequently be subjected to some modifying treatment before being used. In general, deposits of these materials occur in layers or strata, and the different strata are almost always slightly dissimilar in both

physical and chemical composition. By carefully mixing the materials from different strata or from different parts of the bank, therefore, a resulting material of the desired character may usually be obtained. But it not infrequently happens that in order to secure the best results sand or surface clay must be added in an amount depending on the relative "leanness" or "fatness"[1] of the material used. In this connection it may be noted, also, that a chemical analysis of a given fire clay or shale does not necessarily indicate its fitness or unfitness for paving brick. The reason for this is that the quality of the brick after "firing" is no less dependent on the physical arrangement of the minerals than on the chemical composition of the material.

THE MANUFACTURE.

The general processes of manufacture are the same for both fire clays and shale. The raw material in either case is crushed to comparatively small fragments and conveyed by some convenient means to a grinding machine, known in the industry as a dry pan. Briefly, this machine consists of a solid iron plate, approximately 5 feet in diameter, surrounded by a perforated iron surface about 2 feet wide. Outside the perforated surface is a rim some 15 inches in height which serves to prevent the material from escaping otherwise than through the perforations. Upon the solid plate rest two massive crushers or mullers, each weighing from 2½ to 3 tons. The pan is revolved rapidly, causing the mullers to rotate by friction. The material is ground between the mullers and the plate and thrown out by centrifugal force toward the rim, where it escapes through the perforated surface into an elevator, by means of which it is conveyed to the screens.

The particles too large to pass the screens, which should not exceed three-sixteenths inch in mesh, are returned to the dry pan, while the screened material is passed to the mixing machine or pug mill by means of conveyers. In the pug mill, water is admixed with the clay to form a stiff mud, which is fed continuously into the brick machine proper.

The brick machine is an extremely heavy mechanism. It consists essentially of an auger or propeller conveyer, a tapering barrel, and the die or former. The material is forced by means of the auger conveyer into the tapering barrel, which terminates in the die, and issues from the die in a solid column under heavy pressure. For "side-cut" brick this column is approximately 4½ inches by 10 inches in cross section, and the brick are formed by cutting through the column, by means of an automatic device, at intervals of about 3½

[1] "Leanness" and "fatness" refer respectively to the lesser or greater amount of silicate present in the material.

inches. For "end-cut" brick the column has a cross section approximately 4 inches by $4\frac{1}{2}$ inches and is cut into sections about 10 inches long.

In order that the successive courses in a brick pavement may be uniformly spaced, it is necessary that suitable lugs be formed on the brick either at the time they are cut, or later by means of re-press molds. Special shapes, such as nose brick for use next to car tracks, and hillside block, which have one side thicker than the other and which are used on steep grades in order to give the pavement a rough surface, may be made either by special die or special re-press molds.

The next step in the process of manufacture consists in drying the brick. In a properly systematized plant the brick are stacked upon drier cars as they leave the presses in such manner as to permit a free circulation of air between them. The loaded cars are immediately run into a tunnel drier, the temperature of which is maintained at about 100° F. at the entering end. As cars containing "green" brick enter one end of the tunnel, which is usually more than 100 feet long, other cars containing dry brick are being removed at the opposite end. Air circulation in the drier is effected by means of fans or high stacks. During drying the brick lose an amount of moisture equivalent to from 15 to 20 per cent of their own weight.

The brick leave the drier ready for burning, which is the last and undoubtedly the most important step in the process of manufacture. Upon the burning depends largely the quality of the finished product, and it requires the greatest skill so to regulate the temperatures and firing periods as to obtain the best results from a given material. Experience alone can demonstrate the manner in which the burning must be modified in order to suit varying sets of conditions. The kilns in which the burning is done are made of brick and are provided with numerous furnaces. The brick are placed in the kilns so as to permit a free circulation of the gases of combustion and the heated air.

PHYSICAL CHARACTERISTICS.

GENERAL REQUIREMENTS.

Paving brick should be uniform in size, reasonably perfect in shape, free from ragging due to friction in the die, and from deep kiln marks caused by impressions from overlying brick in burning. They should be tough in order to resist crushing, hard in order to resist abrasion, and uniformly graded in order that the pavement may wear evenly. Each brick should be homogeneous in texture and free from objectionable laminations or seams. Fire cracks, caused by too rapid firing, should be limited in number and extent, and the entire brick should be vitrified and should contain neither unfused nor glassy spots.

COLOR.

The color is a valuable guide in inspecting brick from the same plant, but it is of little importance when the brick to be compared are from different factories. For brick manufactured from a particular raw material the color indicates, in a measure, the temperature to which they have been subjected, provided they have been burned under identical conditions. Ordinarily, the darker the color the higher the temperature, and, presumably, the better the brick. The surface color of brick may be very misleading, however, and the color of the interior should be used in making comparisons.

SPECIFIC GRAVITY.

The specific gravity of paving brick was formerly considered of importance in judging their fitness for use in pavements. But it has since been generally conceded that a knowledge of the specific gravity is of comparatively little value. The specific gravity of shale brick is ordinarily between 2.20 and 2.40, and of fire-clay brick between 2.10 and 2.25.

ABSORPTION.

The absorptive power of brick, like their color, is a matter of very slight importance, except for comparing specimens manufactured under identical conditions. It is true that the porosity of the brick increases with the power of absorption, but it is very doubtful if any paving brick possessing an objectionably high absorptive power could pass even a very casual inspection. In other words, a high degree of porosity always manifests itself in other ways more clearly than in the ability of the brick to absorb water.

CRUSHING STRENGTH.

The crushing strength of good paving brick varies from 10,000 pounds to 20,000 pounds per square inch when the load is applied uniformly over the entire top surface of the test specimen, and may be much greater if the area over which the load is applied is less than that of the top surface. Since paving brick in use are seldom required to withstand a pressure of more than about 2,000 pounds per square inch, and since inferior brick may possess relatively very high resistance to crushing, a knowledge of the crushing strength is clearly of little value in comparing the relative excellence of different makes of brick. It is, therefore, usually considered unnecessary to specify a definite requirement as to the crushing strength of paving brick.

TESTING THE BRICK.

Definite methods of testing paving brick have been in general use for only a comparatively few years and have only recently undergone a pronounced change. The object of all tests is to determine whether

or not a given quality of brick is suitable for use in constructing pavements and to furnish a basis for comparing different classes of brick. The methods have, therefore, been repeatedly changed, not only in order to make the results obtained indicate more definitely the quality of the brick, but also with a view to establishing uniformity, so that results obtained in different laboratories may be intelligently compared. A discussion of the most important tests follows in more or less detail.

FIELD TEST.

The general appearance of a paving brick is, to an experienced eye, a valuable indication of its quality and will frequently suggest the advisability of applying routine tests to some particular part of a shipment. Unfortunately the knowledge gained from experience with one kind of brick can not be safely relied upon in inspecting other brick made by a different process or from a different class of raw material. A further limitation to this method of testing lies in the fact that the results obtained do not admit of numerical evaluation, and can not, therefore, be very accurately described. This test is nevertheless valuable, and since no apparatus other than a hand hammer is needed, it can always be employed.

The test consists simply in making a careful inspection of the brick individually and collectively. The size is tested by making measurements, the shape by arranging a number of brick in the order in which they are intended to be placed, and the quality by an examination of both the exterior and interior of a number of samples.

TRANSVERSE TEST.

The transverse strength of a brick is determined by supporting it upon two knife edges and applying a load on the opposite side and midway between the supports by means of a third knife edge. The load is gradually increased until rupture occurs, and the result of the test is expressed in terms of the ratio $\frac{3Pl}{2bd^2}$, called the modulus of rupture. In the above ratio P represents the breaking load in pounds, while l, b, and d represent, respectively, the distance between supports, the breadth of the specimen, and the depth of the specimen, all measured in inches.

The modulus of rupture for good paving brick usually lies between 2,000 and 3,000 pounds per square inch, and frequently varies considerably even with carefully selected specimens which have been manufactured under identical conditions.

RATTLER OR ABRASION TEST.

The rattler or abrasion test is undoubtedly the most important of the tests made on paving brick at present. In making this test the

specimen brick are subjected to destructive influences very similar to those encountered in actual service, and the results obtained, therefore, indicate very closely the effect which traffic may be expected to produce on a pavement constructed of similar brick. The methods of making the test, of which there were formerly a great many, have undergone repeated changes in order that service conditions may be more nearly approached, and also in an effort to bring about uniformity, so that the results obtained may be of the greatest possible scientific value. The method which is now proposed by the subcommittee on paving brick of the American Society for Testing Materials may be briefly described as follows:

The apparatus necessary for making the test, ordinarily called the rattler, consists of a 14-sided barrel of regular polygonal cross section supported on a suitable frame and fitted with the necessary driving mechanism. The staves, each of which forms a side of the barrel, are made of 6-inch 15.5-pound structural steel channels 27¼ inches long. These staves are double bolted to the cast-iron heads of the barrel, which are provided with slotted flanges for holding the bolts. Cast-iron wear plates are bolted to the inside of the barrel heads. The inside diameter of the barrel is 28⅜ inches.

In this barrel is placed what is known as the abrasive charge. This charge consists of two sizes of cast-iron spheres having respective diameters of 3¾ inches and 1⅞ inches and weighing, respectively, 7.5 pounds and 0.95 pound when new. Ten of the larger spheres are used, and the number of the smaller spheres is made such that the weight of the entire charge will approximate 300 pounds. The individual larger spheres are discarded whenever their weight falls to 7 pounds or less and the smaller spheres when they become sufficiently worn by usage to pass through a circular opening having a diameter of 1¾ inches.

The test is made by placing a charge of 10 dry brick in the barrel, together with the abrasive charge, and then revolving the barrel 1,800 times. The number of revolutions per minute is not permitted to fall below 29½ nor to exceed 30½, and the operation is made continuous from start to finish.

The results of the test are reckoned in terms of the loss in weight sustained by the brick, and this loss is expressed as a percentage of the original weight of the brick tested. In determining the loss in weight, no piece of brick which weighs less than 1 pound is considered as having withstood the test.

Good paving brick will ordinarily lose from 18 per cent to 24 per cent of their original weight in the rattler test, and specifications concerning this loss should be prepared with a view to the character of the traffic for which the pavement is designed.

It is also advisable to require a minimum as well as a maximum percentage of loss which any specified sample of the brick may sustain. This is done in order to insure against too much variation between the softest acceptable brick and the hardest brick which may be supplied.

CONSTRUCTION.

PREPARING THE ROADBED.

In forming a roadbed upon which a brick pavement is to be constructed, the essential features to be considered are (1) thorough drainage, (2) firmness, (3) uniformity in grade and cross section, and (4) adequate shoulders.

Thorough drainage can be secured for any particular road only by means of a careful study of the local conditions which affect the accumulation and "run-off" of both the surface and ground water. These conditions vary considerably even in the same locality, and no set of rules can be given which would cover all cases. For example, the material composing the roadbed may be springy, and in this case tile underdrains will probably be necessary. On the other hand, extremely flat topography may make it necessary to elevate the grade considerably above the surrounding land. The nature of the soil, the topography, and the rainfall must all be considered if a system of drainage is to be planned properly.

The second requirement, firmness, can be secured only after the road has been properly drained. Soils which readily absorb moisture can not be properly drained in wet weather and should not be permitted to form a part of the subgrade. In order that the subgrade may be unyielding, it is also necessary that the roadbed be thoroughly compacted. In forming embankments the material should be put down in layers not over 8 inches thick, and each layer should be thoroughly rolled. In excavation care should be exercised, if the material is earth, not to permit plows or scrapers to penetrate below the subgrade. The subgrade in both excavation and embankment should be brought to its final shape by means of fine grading with picks and shovels and rolling.

When completed the subgrade should be uniform in grade and cross section; otherwise the foundation must be made unnecessarily thick where depressions occur, in order that its grade and cross section may be uniform and its thickness not less at any point than that required. The subgrade should be repeatedly rolled and reshaped until the desired shape is secured. If curbs are constructed independent of the base they should be set before the final finishing, in order that they may be made to serve as a guide for this work.

The shoulders should never be less than 4 feet wide and should consist of some material which compacts readily under the roller and

does not readily absorb water. Not infrequently one of the shoulders is made sufficiently wide to form an earth roadway parallel to the brick pavement. Such an arrangement serves to relieve the pavement of considerable traffic during favorable seasons and also affords some advantage to horse-drawn traffic. The general method of constructing shoulders for brick roads is not essentially different from that employed for other types of pavements.

CURBING.

Brick pavements, as generally constructed, should be supplied with strong, durable curbing, both on the sides and at the ends. Otherwise the marginal brick will soon become displaced by the action of traffic, and their displacement will, of course, expose the brick next adjoining, so that deterioration might eventually spread over the entire pavement. Properly constructed curbing, on the other hand, will hold the pavement as in a frame and enable the brick to present their combined resistance to the destructive influences of traffic.

Satisfactory curbs may be constructed of stone, Portland cement concrete, or vitrified clay shapes made especially for this purpose. Wood has also been used for curbs to a limited extent, but when it is considered that the life of a brick pavement under ordinary conditions should far exceed the life of any wood curb which might be devised, the economy of employing a more durable material is readily apparent.

Stone curbing may be made from any hard, tough stone which is sufficiently homogeneous and free from seams to admit being quarried into blocks not less than 4 feet long, 5 inches thick, and 18 inches deep. On account of their ordinarily homogeneous structure, granite and sandstone are probably more used for curbs than any other kind of stone.

All stone curbing should be hauled, distributed, and set before the subgrade is completed. The individual blocks should be not less than about 4 feet long, except at closures, and should ordinarily have a depth of from 16 to 24 inches, depending on soil conditions and on whether the curb is to project above the surface, forming one side of the gutter. The neat thickness need never be greater than 8 inches and, where the traffic conditions are not severe and the quality of the stone is good, a thickness of 6 inches will ordinarily prove satisfactory. Stone curb should always be set on a firm bed of gravel, slag, or broken stone, not less than 3 inches thick, or on unusually firm earth, and should be provided with a backing of the same material on the shoulder or sidewalk side. Figure 1 shows a typical stone curb in place.

Where suitable stone is not readily available or when from any cause the cost of stone curbing would prove excessive, a curb con-

structed of Portland cement concrete may frequently be advantageously used. Concrete curbs may be constructed alone or in combination with either a concrete gutter or a concrete foundation. When constructed alone they should have approximately the same cross-sectional dimensions as stone curbs and should be constructed in sections about 8 to 10 feet in length. Figures 2, 3, and 4 show the three common types of concrete curbs.

Vitrified clay curbing should be set in much the same manner as that described for stone curbing. The principal additional requirement is that, since vitrified clay is a lighter material than stone and the curb sections are ordinarily shorter, the bedding must be made correspondingly more secure in order to prevent displacement.

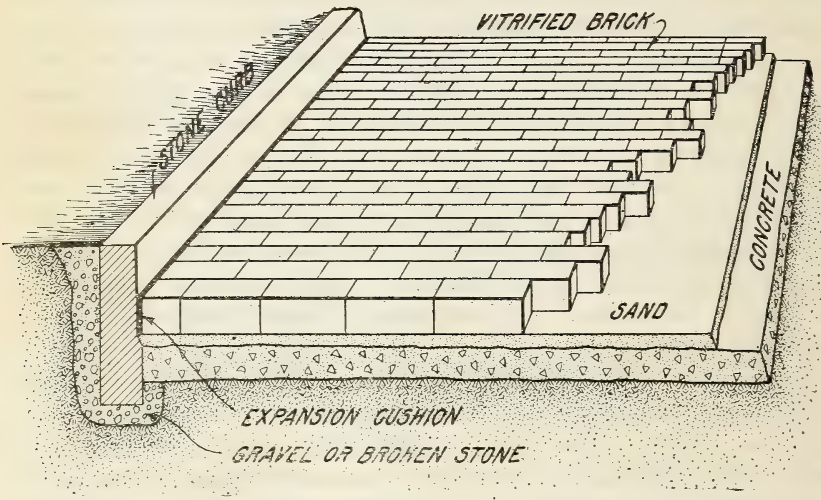


FIG. 1.—Proper method of constructing stone curb.

Several sections of brick pavement in which curbs were altogether omitted were constructed during 1915 in the State of Illinois. The methods employed in constructing these pavements, which are designated "monolithic," are described on page 21.

THE FOUNDATION OR BASE.

A firm, unyielding foundation is one of the most essential features of a brick pavement. This fact can be more readily appreciated when it is considered that the surface of a brick pavement is made up of small individual blocks, any one of which might be easily forced down, causing unevenness in the surface, if the foundation were poor; and since the ability of the pavement to resist wear depends very largely on the smoothness of the surface, every reasonable precaution should be taken to prevent any unevenness from developing. The

fact that more brick pavements have failed on account of defective foundations than from any other cause should never be lost sight of by those planning and supervising this class of work. Plate I shows typical illustrations of what is likely to occur whenever this feature of the work is neglected. Both of the roads here illustrated were comparatively new, but failed when subjected to heavy motor-truck traffic. The one shown in Plate I, figure 1, had a rolled gravel foundation constructed under inadequate specifications and poor inspection, while in the other case a 4-inch concrete foundation was specified, but an inspection made after failure revealed that the concrete was of an inferior quality and that its thickness was generally less than that required by the specifications.

The proper type of foundation or base depends largely on the material composing the subgrade and the character of traffic for

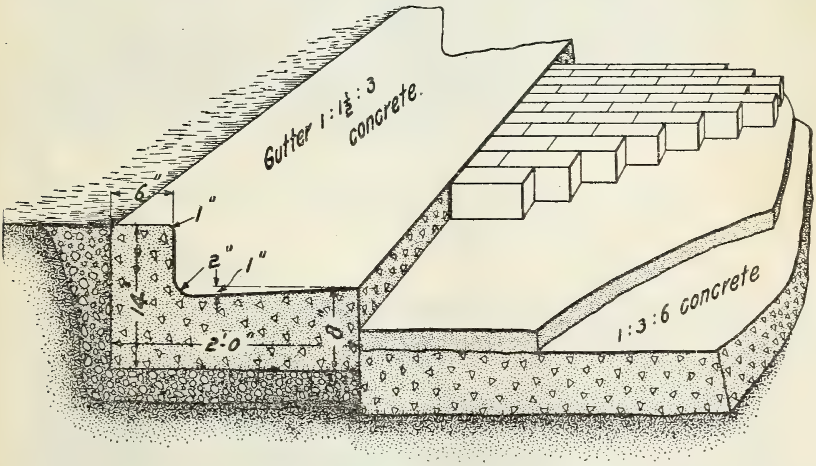


Fig. 2.—Concrete curb and gutter combined.

which the road is designed. Where the traffic is comparatively light and the subgrade is composed of some firm material which does not readily absorb water, a very satisfactory base may be constructed of broken stone. Where the traffic is comparatively heavy or where the material composing the subgrade is at all unstable, a monolithic concrete base should be used. Bases consisting of a course of brick laid flat upon a previously compacted layer of gravel or broken stone have sometimes been used, and pavements constructed upon bases of this kind, ordinarily called "double-layer" pavements, have in general proved satisfactory. At the present time, however, such bases can rarely be constructed at less cost than the more durable concrete bases, and they will therefore be given no further consideration here.

Broken-stone bases should be from 6 to 8 inches thick after compacting and should be constructed in two or more courses just as in

the case of first-class macadam roads. The stone should be durable, and should be graded in size between certain reasonable, fixed limits. It should be uniformly spread on the road, either from dumping boards by means of shovels or from wagons especially designed to spread the material as it is being dumped. Where whole loads are dumped in one place and then spread out to the required depth, it is very difficult to obtain uniform density. Usually those spots where the loads are dumped are more densely compacted than the rest of the base, and this lack of uniformity very soon manifests itself by producing unevenness in the surface of the pavement. The broken stone should be compacted in the usual manner by rolling with a

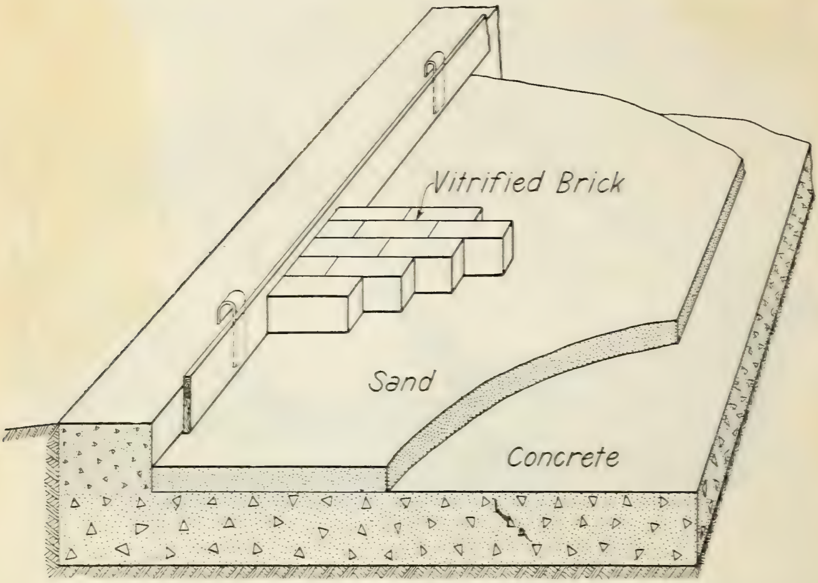
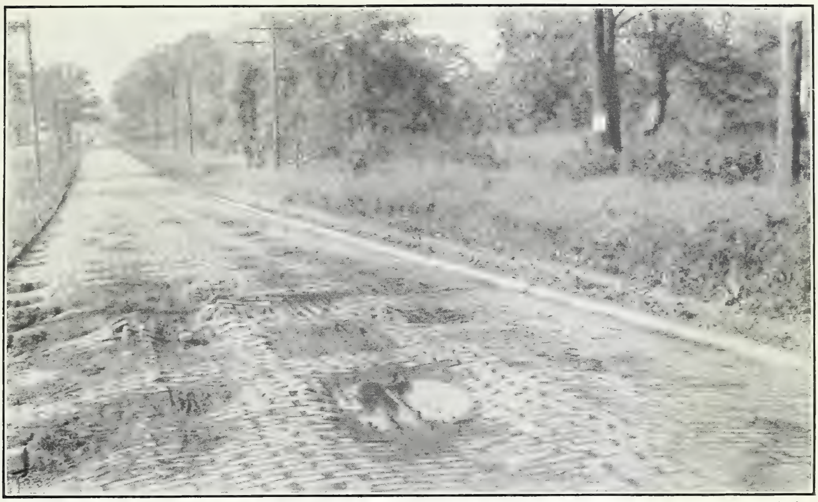


FIG. 3.—Making provision for expansion cushion.

power roller weighing not less than about 10 tons, and sufficient stone screenings and coarse sand to fill the voids should be spread and flushed into the base while the rolling is in progress. When complete the base should present a surface uniform in grade and cross section and parallel to the proposed surface of the finished pavement.

Concrete bases are unquestionably better adapted for brick pavements than any other type. They are practically monolithic in form, nearly impervious to water, and possess a relatively high crushing strength. All of these qualities may be obtained with a relatively "lean" concrete if the subgrade has been properly prepared. Under ordinary circumstances a satisfactory base may be constructed of



OPRRE 12409

FIG. 1.—FAILURE OF BRICK ROAD NEAR ZANESVILLE, OHIO, DUE TO DEFECTIVE GRAVEL FOUNDATION AND 11-TON MOTOR-TRUCK TRAFFIC.

OPRRE 13006

FIG. 2.—FAILURE OF BRICK ROAD NEAR MANSFIELD, OHIO, DUE TO DEFECTIVE CONSTRUCTION AND HEAVY MOTOR-TRUCK TRAFFIC.

OPRRE 13123

FIG. 1.—BRICK ROAD ON SAND FOUNDATION, HILLSBORO COUNTY, FLA.

Settlement along left curb might have been avoided by better preparation of the foundation and by use of Portland cement grout for filling the joints.

OPRRE 13127

FIG. 2.—BRICK ROAD AT ORLANDO, FLA., SHOWING DISPLACEMENT OF MARGINAL BRICK DUE TO ABSENCE OF CURB.

concrete composed of 1 part of Portland cement, 3 parts of sand, and from 5 to 7 parts of broken stone or screened gravel.

The sand should be clean and well graded in size, and the stone or gravel should conform to the usual requirements for coarse aggregate to be used in concrete construction.

Brick pavements have in some cases been constructed with the subgrade as a foundation, and where the materials composing the subgrade possess considerable supporting power under all weather conditions to which the road is subjected, this method may prove fairly satisfactory. Perhaps the most notable examples of brick roads constructed in this way are to be found in the peninsular section of Florida, where the soil is composed essentially of sand and where there is no danger of upheaval due to frost action. At best, this method of construction could hardly prove satisfactory for any ordinary soil conditions above the thirty-fifth parallel of latitude, and even below that latitude it should necessarily be confined to localities where the soil is composed of sand, gravel, or some other material

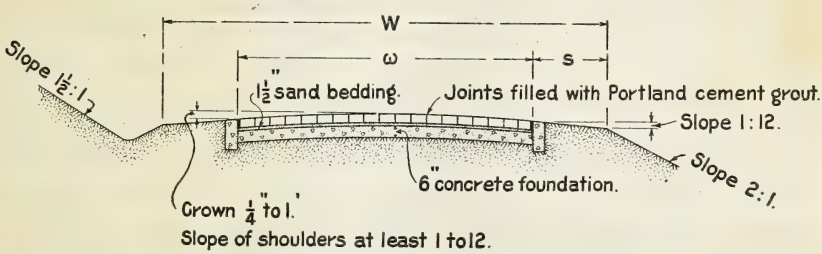


Fig. 4.—Typical section for a brick road.

which does not lose its stability when wet. Sand is the only material of this kind which is at all widely distributed. The precautions most necesary to observe in preparing sand foundations may be briefly described as follows:

(1) The road should be so graded and drained as absolutely to prevent the foundation from becoming saturated with either storm or ground water after the brick are laid.

(2) The entire roadway should be thoroughly saturated with water while it is being compacted, and a roller weighing not less than 10 tons should be used for compacting. Dry sand can not usually be compacted by rolling.

(3) Adequate stone or concrete curbs should always be provided. At present wooden boards are being used in lieu of curbs for many of the Florida roads, and in some cases this substitution can perhaps be justified by the immediate necessity for improving a large mileage of roads without suddenly increasing taxation to an unwarranted burden. On the other hand it seems very doubtful if any community

which can not afford proper construction in the beginning should select such an expensive type of surface for their roads.

(4) The material composing the foundation should be of a uniform character and free from vegetable matter of any kind. After the curbs are set, the foundation should be rerolled and reshaped until it is firm and unyielding and conforms to the required grade and cross-section. In order to accomplish this final shaping, the sand must be kept moist, and it is usually necessary to provide a pipe line along the work to supply water for sprinkling the foundation.

Plate II, figure 1, shows how a brick road on a sand foundation has settled under the action of traffic. This settling would probably not have occurred if the above precautions had all been observed at the time of construction, though the fact that sand, instead of Portland cement grout, was used for filling the joints was no doubt a contributing weakness.

BEDDING.

Since it is practically impossible to construct an absolutely smooth base, and since there is always a slight variation in the size of paving brick, owing to differences in the amount of shrinkage at the time of burning, it is necessary to provide an adjustable bedding of some kind between the base and the brick in order to secure an even surface and a uniform bearing for the brick. Until recently sand has been almost exclusively used for this purpose and has in general proved satisfactory. The objections which have been advanced against the sand bedding are, first, that it may become saturated with water, which upon freezing might damage the pavement; second, that a gradual movement of the sand may occur under the jarring action of traffic and in this way the surface of the pavement may eventually become distorted; and, third, that the use of some material for the bedding which would bond the brick to the base would enable the pavement to distribute concentrated loads over a greater area of the subgrade than where a sand cushion is used. It has also been claimed that the sand bedding, by separating the brick from the base, is responsible for much of the noise produced by traffic over brick pavements. In order to overcome these objections some engineers are now providing that the bedding shall be constructed of a dry mixture of sand and Portland cement instead of sand alone. This mixture, which is called "dry mortar," becomes wet when the brick are sprinkled just prior to grouting, and upon hardening forms a partial bond between the base and the brick. When such a bond is formed the bedding is not disturbed by the jarring action of traffic and is also partially impervious to water. The dry mortar bedding is at present employed only where the base is made of concrete, and its use has by no means become general, even with the concrete base.

The proper thickness for the bedding depends, of course, upon the extent of the inequalities in the brick and the foundation. In the past, 2 inches has been the most usual thickness, but as the accuracy secured in constructing the base has increased, and as the size of paving brick has become more nearly uniform, the necessary thickness for the bedding has naturally diminished. At present a thickness of $1\frac{1}{2}$ inches is considered conservative where the bedding consists of sand alone, but where dry mortar is employed the inequalities should be so reduced that a thickness of 1 inch will be sufficient, because it is cheaper to make the surface of the base uniform than to supply the additional dry mortar which would otherwise be required.

Sand bedding should consist of moderately clean sand and be free from pebbles. If dirt or vegetable matter is present, it will soon be leached out and cause unevenness to develop in the pavement, while pebbles prevent the brick from securing a uniform bearing and ultimately produce the same result. It is also important that the sand should be dry when spread, especially if it is fine, because a comparatively small amount of moisture increases the volume of fine sand considerably, and moisture when present is not, as a rule, uniformly distributed. Even if it were uniformly distributed at the start, some spots would dry out more rapidly than others while the spreading was under way, and a lack of uniformity would thus be produced in the bedding.

In forming the bedding the sand is uniformly spread over the base to a depth slightly in excess of that desired, and is then smoothed off by drawing over it a template shaped to conform with the cross section of the finished pavement. The length of the template is ordinarily made equal to the width of the pavement where this is less than about 25 feet, and equal to half the width for wider pavements. Timber guides may be laid in the same direction as the pavement for the template to slide on, or the curbs may be made to serve as guides where this is convenient.

After the bedding material is spread and uniformly "struck off" with the template to a depth slightly in excess of that required, it should be thoroughly compacted by rolling with a hand roller weighing from 300 to 400 pounds, and any depressions which form should be corrected. This is necessary in order to secure uniform density and to prevent unequal settlement of the surface.

If a dry mortar bedding is to be employed, the sand used should be clean and the manner of spreading and compacting the bedding should be practically the same as for sand alone. The proportion in which the sand and cement should be mixed is a subject regarding which there is more or less uncertainty at present. One part of

cement to five parts of sand is probably the most usual proportion. The mixing is generally done in a mechanical mixer, and the material is spread and compacted just in advance of the brick layers. It is of course essential that the bedding be kept dry until after the brick are laid.

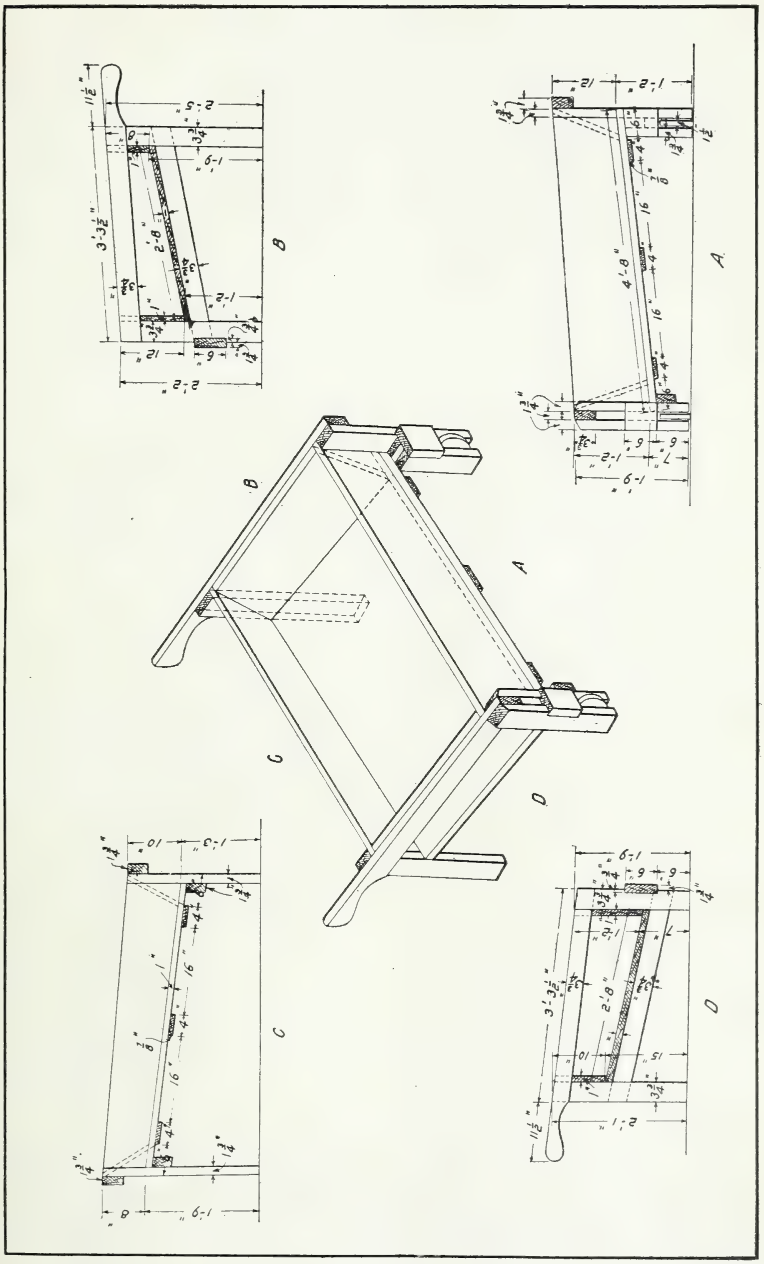
HANDLING AND LAYING THE BRICK.

The brick may all be hauled and piled at convenient intervals along the sides of the roadway before grading is begun, or, if more convenient, they may be delivered as needed on the work. Hauling over the finished pavement with wagons until it is complete and opened to traffic should be avoided. If the brick are delivered on the work as needed, they should be unloaded from the wagons outside of the curb and carried to the pavers, either by hand or in wheelbarrows. Plank trackways should also be provided over the newly laid pavement for the wheelbarrows when they are used.

The brick should in all cases be uniformly piled by hand on the new pavement conveniently close for the pavers, and each brick should be so placed that the regular operation of picking it up and placing it in the pavement will bring the best edge up. This method of handling the brick requires somewhat more labor than the common method of dumping them from wheelbarrows, but it eliminates to a great extent the practice of picking out and turning over chipped or kiln-marked brick after the pavement is laid. This is very objectionable on account of the disarrangement of the sand cushion, which is frequently occasioned.

The brick should be laid on edge and in uniform courses, running at right angles to the line of the pavement, except at intersections; and in order to "break the joints" each alternate course should begin with a half brick. In laying the brick the pavers stand on the pavement already laid and, be ning at the curb each time, carry across as many courses together as they can conveniently reach. The courses should be kept straight and close together, and, if necessary, each block of 8 or 10 courses may be driven back by means of a light sledge and a piece of straight timber approximately 2 by 4 inches by 5 or 6 feet long, though no heavy driving should be permitted. The brick should also be laid close together in the courses.

After the brick are laid the pavement should be carefully inspected, for the purpose of detecting soft or otherwise defective brick. Misshapen or broken brick may be detected by the eye alone, and the soft brick by sprinkling the pavement with water. The soft brick appear comparatively dry while the water is being applied and comparatively wet after the sprinkling is stopped. All defective brick should of course be replaced by others which meet the requirements of the specifications.



PLAN FOR GROUT BOX HAVING LOW CORNER.

OPRRE 9114

OPRRE 9791

FIG. 1.—FINE GRADING.

OPRRE 9790

FIG. 2.—ROLLING.

PREPARING THE SUBGRADE FOR A BRICK ROAD.

While there are a number of cases where brick have been laid flat and have made fairly satisfactory pavements for light traffic, there are probably very few cases where this practice has proved really economical in the long run.

TRUING THE SURFACE.

After the pavement has been laid and all defective brick have been replaced to the satisfaction of the engineer, the next step is to sweep the surface clean, and smooth out all inequalities by means of ramming and rolling. The rolling should be done with a power roller weighing from 3 to 5 tons, and the pavement should ordinarily be rolled in both longitudinal and diagonal directions. The longitudinal rolling should be done first, and should begin at the curbs and progress toward the crown. The roller should pass at least twice over every part of the pavement in each direction. In order to neutralize any tendency which the brick may have to careen under the roller, the number of forward trips over any part of the pavement should equal the number of trips backward over the same part.

In places where it is impracticable to use the roller for truing the surface—such, for example, as along the curbs or concrete gutters or around manholes—the brick should be brought to a true surface by means of ramming. For this purpose a wooden rammer loaded with lead and weighing from 80 to 100 pounds may be used. The blows of the rammer should not fall directly upon the brick, but should be transmitted through a 2-inch board laid parallel to the curb.

After the pavement has been trued up, as described above, it should be inspected again for broken or otherwise damaged brick, and also for those which have settled excessively, owing to some lack of uniformity in the bedding. All defects should be corrected, and the areas disturbed in making the corrections should be brought to a true surface by tamping or rolling. When the work of truing the surface is finished, the brick should be evenly bedded, but the amount of bedding material forced up into the joints should be inappreciable. If this is not the case, it is evidence that either the bedding has been poorly prepared or the rolling has been excessive.

FILLING THE JOINTS.

In order to keep the brick in proper position and protect the edges from chipping it is necessary to fill the joints with some suitable material before the road is opened to traffic. The materials which have in the past been most commonly used for this purpose are sand, various bituminous preparations, and a grout made of equal parts of Portland cement and fine sand mixed with water.

Sand is the least expensive of these materials, but there are several very serious objections to its use as a joint filler: (1) It does not protect the edges of the brick; (2) it is easily disturbed in cleaning the pavement and is likely to be washed out by rain on steep grades; (3) it does not entirely prevent water from penetrating through to the foundation; and (4) it does not bond the individual brick together and so enable them to present a concerted resistance to traffic.

The bituminous fillers vary considerably in quality and efficiency, but all are more or less unsatisfactory. One of the principal objections to their use is based on their tendency to run out of the joints into the gutters during warm weather and to crack and spall out during cold weather. This tendency can, of course, be partially overcome by exercising proper care in selecting the materials. It should also be noted in their favor that brick pavements, the joints of which have been filled with bituminous preparations, are ordinarily less noisy than those in which a Portland cement grout filler has been used. The grout filler is unquestionably very much superior from a standpoint of durability, however, and the excessive noise under traffic which has been frequently observed in connection with its use can be largely eliminated by the use of proper bituminous expansion cushions along the curbs. It is, therefore, recommended as better adapted for filling the joints in brick pavements than any other material which has been commonly used for that purpose.

When the joints of a brick pavement are properly filled with Portland cement grout the individual brick are firmly bonded together and, since the material composing the joints scarcely wears more rapidly than the brick, the edges of the brick are well protected.

When the pavement is constructed on a foundation other than concrete the advantages of using the grout filler are especially evident because of the protection thus afforded the foundation.

A satisfactory method for mixing and applying the grout filler by hand may be described as follows: Grout boxes, constructed in such manner that when resting on a level platform one corner will be lower than the others, should first be provided. A suitable design for such boxes is shown in Plate III. The number of boxes required depends on the width of the pavement; ordinarily one box to each 10 feet of width will be found sufficient. The grout, which should be put on in two applications, is prepared in batches each of which consist of a quantity of cement not exceeding one sack, a like amount of fine, clean sand, and water. The sand and cement should first be thoroughly mixed dry and sufficient water then added to produce a liquid mixture. The consistency of the mixture for the first application should be approximately the same as that of ordi-

nary cream and for the second application it should be somewhat thicker. Mechanical mixers have also been satisfactorily used for mixing and spreading the grout, and where the amount of work to be done is sufficient to warrant such an initial outlay, they are usually economical.

The pavement should be cleaned and thoroughly sprinkled as a preliminary to making the first application of grout, and it should be kept moist by gentle sprinkling while this application is being made. The grout should be swept into the joints immediately after it is removed from the boxes and spread upon the pavement. For this purpose a coarse rattan or fiber push broom should be used in the first application and a squeegee in the second application. The squeegee is usually made by clamping a piece of four-ply rubber belting or some other similar material, about 6 by 20 inches in size, between two pieces of board and attaching a suitable handle. The grout in the boxes should be continually stirred until the last of it is removed, otherwise a separation of the sand and cement will almost certainly occur.

The first application should proceed sufficiently far in advance of the second for the grout of the first application to settle, but not to take its initial set before the second application is made. Usually both applications are made by the same crew of laborers. They simply turn back after having covered the allowable distance with the first application and, mixing the grout in the same boxes, bring up the second application. The second application of grout should completely fill the joints flush with the top of the brick.

PROTECTING THE PAVEMENT.

After the joints are filled as described above and the grout has taken its initial set, the entire surface should be covered to a depth of approximately 1 inch with sand or fine earth. This is done to protect the pavement from the weather and to keep it in a moist condition while the grout is hardening. If necessary, in order to keep the covering moist, it should be occasionally sprinkled for several days after it is spread.

The covering should be permitted to remain on the surface for at least 10 days, and during this period the pavement should be kept entirely closed to traffic. If the weather is unfavorable, the length of time during which traffic is kept off the road should be increased.

EXPANSION CUSHIONS.

It has been customary in the past to provide both longitudinal and transverse bituminous expansion cushions in grout-filled brick pavements, but recent practice has demonstrated that the transverse

cushions may be advantageously omitted if proper longitudinal cushions are provided. The principal objection to the use of transverse expansion cushions is based on the fact that the material composing the cushions frequently softens during warm weather and runs out toward the curb, thus leaving the edges of the adjoining brick exposed to destructive impact from the wheels of passing vehicles. Even if the cushion consists of a material which does not run in warm weather, it is necessarily softer than the brick, and the natural result is still the development of unevenness in its immediate vicinity. No such objection can exist concerning longitudinal expansion cushions if they are placed adjacent to the curbs and constructed of proper material. They not only furnish a means for the pavement to expand and contract with changes in temperature, but they also eliminate to a large extent the disagreeable rumbling which has been so frequently associated with grout-filled brick pavements.

The bituminous material of which the expansion cushions are made should be such as to remain firm in summer and not to become brittle in winter. It should also possess the quality of durability. In order to insure that any given material is suited for such a purpose, it is usually considered necessary to prescribe certain laboratory requirements to which it must conform, and examples of these, which have been found to give good results, are contained in the section entitled "Typical specifications." (Cf. p. 26 et seq.)

Expansion cushions should be provided for at the time the brick are laid. This may be done by placing a board of the required thickness on edge adjacent to each curb, as shown in figure 3. Small iron wedges, such as are shown in this figure, may be inserted between the curb and the board at the time the board is set. These wedges may be readily loosened and removed after the brick have been laid and grouted, and may consequently be made to facilitate the removal of the board which provides space for the bituminous filler. If preferred, a bituminous felt board may be satisfactorily substituted for the poured cushion just described.

The proper thickness for expansion cushions is a matter concerning which much difference of opinion exists among highway engineers. Some engineers advocate a minimum thickness of 1 inch, while others claim to have secured their best results by using expansion cushions having a minimum thickness as low as three-eighths inch for very narrow pavements. It is generally agreed that the thickness of the cushion should vary with the width of the pavement. The following suggestions for proportioning the cushion are offered as being fairly representative of the best practice.

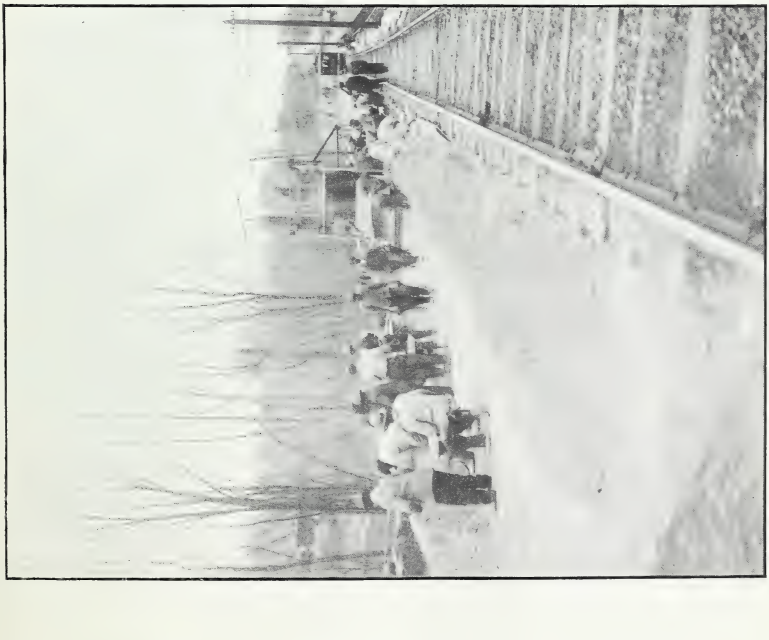


FIG. 1.—MIXING CONCRETE FOR THE BASE.

FIG. 2.—FINISHED CONCRETE BASE.

EXPERIMENTAL ROAD AT CHEVY CHASE, MD.

OPRRE 9231

FIG. 1.—SPREADING SAND CUSHION.

OPRRE 9225

FIG. 2.—ROLLING SAND CUSHION.

EXPERIMENTAL ROAD AT CHEVY CHASE, MD.

OPRRE 9227

FIG. 1.—LAYING THE BRICK.

OPRRE 9226

FIG. 2.—ROLLING THE PAVEMENT.

EXPERIMENTAL ROAD AT CHEVY CHASE, MD.

OPRRE 9229

FIG. 1.—FILLING THE JOINTS, FIRST COAT.

OPRRE 9223

FIG. 2.—FILLING THE JOINTS, SECOND COAT.

EXPERIMENTAL ROAD AT CHEVY CHASE, MD.

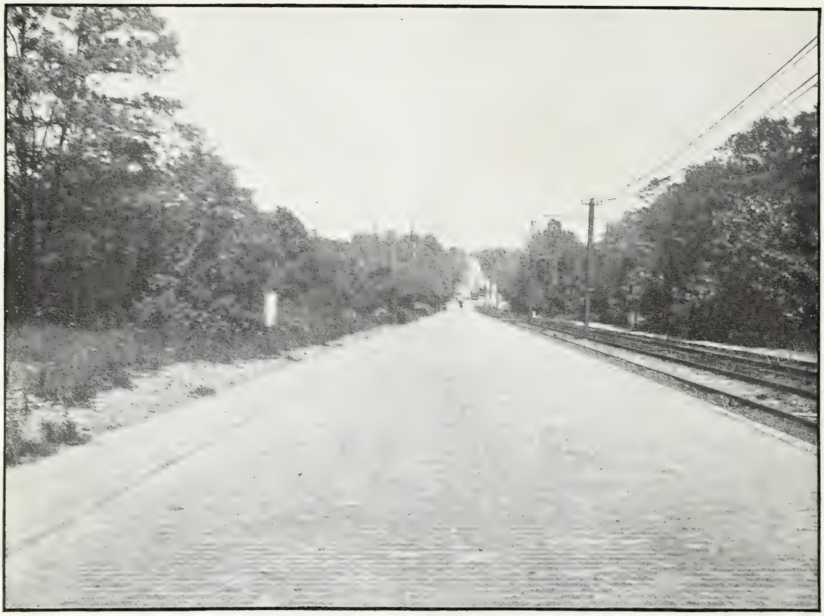
OPRRE 9230

FIG. 1.—FINISHED BRICK PAVEMENT PROTECTED BY SAND COVERING.

OPRRE 9991

FIG. 2.—SHOWING PROPERLY FILLED GROUT JOINTS.

EXPERIMENTAL ROAD AT CHEVY CHASE, MD.



OPRRE 9987

FIG. 1.—EXPERIMENTAL ROAD AT CHEVY CHASE, MD.

Finished pavement in service.

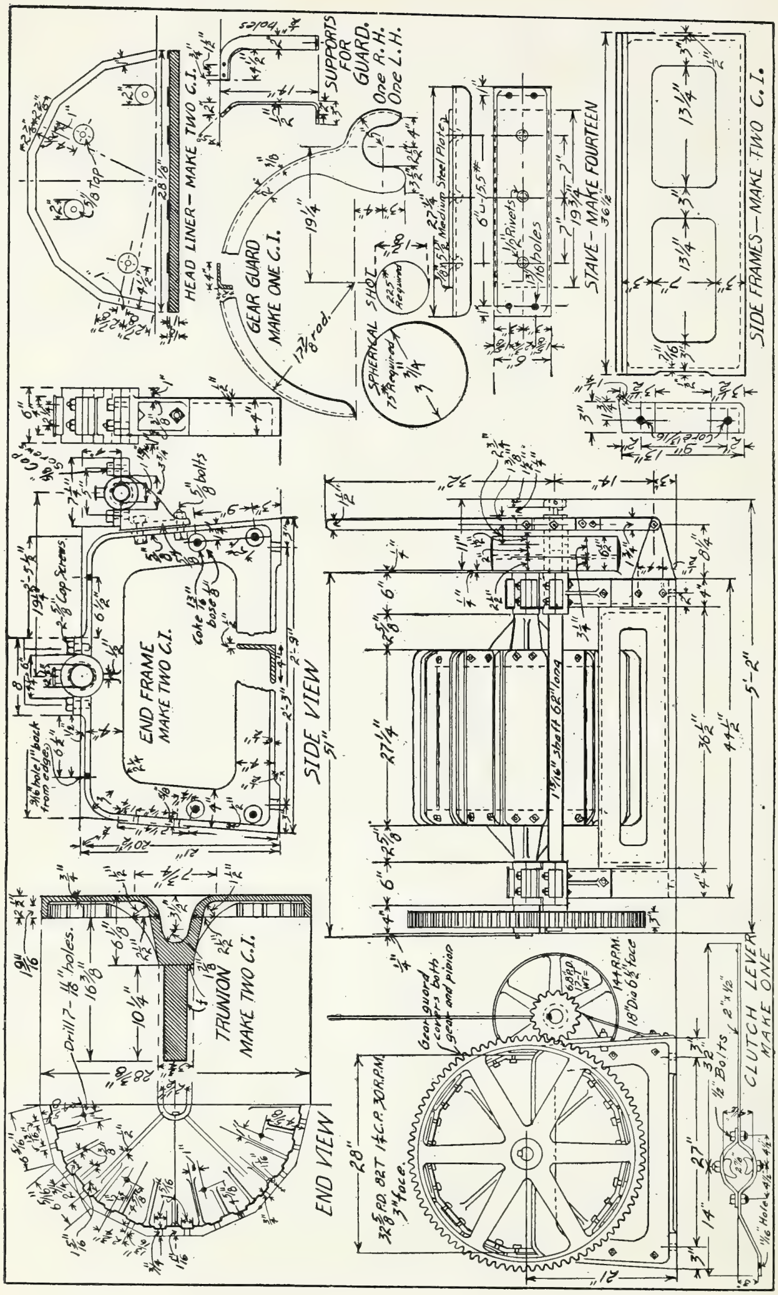
OPRRE 6044

FIG. 2.—GROUT-FILLED BRICK PAVEMENT, HAVING LONGITUDINAL JOINTS IN CENTER AND OCCASIONAL TRANSVERSE JOINTS FILLED WITH SOFT FILLER.

Unsightly appearance at right caused by widening roadway.

OPRRE 11134

GROUTED BRICK ROAD NEAR CLEVELAND, OHIO, SHOWING LONGITUDINAL CRACKS SUCH AS FREQUENTLY OCCUR IN BRICK PAVEMENTS, THE CAUSE OF WHICH CAN NOT ALWAYS BE DEFINITELY EXPLAINED.



PLAN FOR RATTLER.

TABLE 1.—*Ratio of thickness of cushions to width of roadway.*

Width of roadway (feet).	Thickness of cushion (inches).
20 or less	$\frac{1}{2}$
20 to 30	$\frac{3}{4}$
30 to 40	1
Over 40	$1\frac{1}{4}$

Plates IV to VIII, and Plate IX, figure 1, show the various steps in the construction of a brick pavement. Plate IX, figure 2, and Plate X, figure 1, show the finished pavement as it should appear, and Plate X, figure 2, shows the advantage possessed by grout-filled joints over joints filled with a soft material. The partial or total failures shown in Plates I, II, and XI are intended to emphasize the importance of employing proper methods, materials, and workmanship in brick-pavement construction.

"MONOLITHIC" BRICK PAVEMENTS.

During the year 1915 several sections of brick road were constructed in the vicinity of Paris, Ill., in accordance with an unusual method which offers at least partial promise of showing advantages not possessed by the common methods of construction now in use. The novel features of this work are: (1) The brick are laid upon a green concrete base with no intervening bedding other than a very thin layer of dry mortar spread by means of a specially designed templet; (2) no curbs are employed; (3) the construction of the base, the laying of the brick, and the grouting all proceed sufficiently close together to make the pavement practically a monolith, from which fact this type of brick pavement has been designated "monolithic."

The advantages which the new type of brick pavement appears to possess may be briefly enumerated as follows:

(1) Economy in cost of construction. In addition to the saving in materials and labor effected by omitting the curbs, sand bedding, and expansion joints the labor cost can probably be somewhat further reduced by having the construction of the concrete base and the laying of the brick carried on under the same organization. The reduction in the time during which it is necessary to keep the highway closed to traffic, while the improvement is being made, is also an indirect economy.

(2) The elimination of the sand bedding would appear to be of advantage from a construction standpoint, because it is liable to be disturbed and to cause trouble in case of a heavy rain during construction. Sometimes, even after the pavement is completed, the sand is disturbed by water getting in between the brick and the base

through poorly grouted joints, or otherwise. Also, when a sand bedding is used, the joints between the brick are nearly always partially filled by sand being pushed up into them when the brick are rolled, and the effectiveness of the grout may be thereby greatly reduced.

(3) If the pavement continues to act as a monolith, the pressure on the subgrade, due to concentrated loads on the surface, will be much better distributed for the same depth of brick and base than if the two were separated and able to act independently.

The two principal objections to this type which suggest themselves at present are:

(1) The difference in the coefficients of expansion of brick and concrete may eventually cause a separation of the two materials, and as there is no adjustable bedding between them, any relative movement might result in shattering the bond between the brick and the grout. The only warrant for this apprehension at present, however, is in theory and not in fact.

(2) Whenever it becomes necessary to renew or repair the surface of the pavement, it will probably be necessary to renew the base also.

Until sufficient time has elapsed to show how this new type of pavement will be affected by changing temperatures and increasing age, no specific recommendations can be made concerning its adoption. But the indications are certainly sufficiently promising to warrant a careful watch being kept on these pavements and to encourage the undertaking of further experiments.

COST OF BRICK PAVEMENTS.

The cost of brick pavements varies widely and is affected by so many influences that it is difficult to attempt to derive a general expression showing the relation between probable cost and local conditions. The prices of brick, as also the prices of the various materials entering into the foundation, vary greatly according to the locality and the freight rate. The cost and efficiency of labor is also far from being constant. Furthermore, the material composing the subgrade and the method of preparing it may exert a marked influence on the cost of the pavement. The following statements regarding cost, then, must be considered as representing average conditions, and care must be exercised in applying them to special cases. They are intended as a guide in preparing estimates of probable cost.

The grading is usually paid for by the cubic yard, and the cost, of course, varies with the character of the soil and the necessary amount of excavation. In light, easily loosened soils, grading may usually be done at from 25 to 40 cents per cubic yard. In hard earth con-

taining more or less loose rock the cost per cubic yard generally runs from 40 to 75 cents, while grading in solid rock may sometimes cost as much as $1.50 per cubic yard. The cost of the rough grading should be considered entirely apart from the cost of the pavement.

The cost of shaping and rolling the subgrade after the rough grading is completed will ordinarily vary from 3 to 5 cents per square yard. This cost should be included with the other items which make up the cost of the pavement.

The cost of the curbs varies with the character of the material used. Stone curbs ordinarily cost from 25 to 75 cents per linear foot, while curbs made of Portland cement concrete cost, as a rule, from 20 to 50 cents per linear foot. The higher prices for the concrete curbs apply principally to special cases requiring extra form work or considerable extra material.

The cost of the foundation depends largely on the cost of the materials with which it is constructed. Gravel or broken stone can usually be spread and rolled at from 5 to 7 cents per square yard, while the cost of these materials, delivered, varies from $0.60 to $2 per cubic yard. Mixing and placing concrete usually costs from 35 to 75 cents per cubic yard, according to the amount of work to be done and the methods employed, and the cost of the materials, delivered, ordinarily varies from $2.50 to $4.50 per cubic yard of concrete.

The cost of paving brick at the kiln varies from about $13 to $16 per thousand. Estimating 40 brick to the square yard, each 1,000 brick cover approximately 25 square yards, which makes the cost at the kiln per square yard of pavement vary from 55 cents to about 65 cents. These figures mean very little, unless the kiln is located conveniently near where the brick are to be used, for freight charges not infrequently amount to more than the cost of the brick.

The amount of joint filler required varies of course with the thickness of the joints. If grout is used as a filler, it is customary to estimate about 1 barrel of cement to each 25 square yards of pavement. If a bituminous filler is used, not more than about 1 gallon of bitumen should be required for each square yard of pavement.

A force consisting of one paver and five laborers should place on an average about 220 square yards of brick per 10-hour day; while supervision, rolling, and incidental expenses are ordinarily equivalent to the cost of hiring about three and one-half additional laborers.

If C = cost of cement per barrel, S = cost of sand per cubic yard, A = cost of coarse aggregate per cubic yard, B = cost of paving bricks per 1,000, and L = cost of labor per hour, with all materials considered delivered on the work and all costs expressed in cents, then the probable cost of constructing a brick pavement, including the

subgrade, a 6-inch concrete foundation, and suitable curbs, may be estimated by substituting in the formula:

$$\text{Cost per square yard} = 1.90\text{ L} + .213\text{ C} + .138\text{ S} + .157\text{ A} + .040\text{ B}.$$

The cost as estimated from this formula should usually be increased by about 10 per cent to allow for wear on tools and machinery and to guard against unforeseen contingencies. If it is desired to use a different thickness of foundation, it is safe to assume that each inch subtracted or added to the thickness of the foundation will make a corresponding difference of from 8 to 12 cents in the cost per square yard.

MAINTENANCE OF BRICK PAVEMENTS.

If brick pavements are properly constructed at the start, the work of maintaining them is very slight. Under the closest inspection, however, some inferior material is likely to become incorporated either in the foundation or in the surface, and it is therefore very important that a brick pavement be very carefully watched for the first few years of its life to see that no unevenness develops either because of defective brick having been used in the surface or because of insufficient support from the foundation at any point. Whenever any unevenness develops, it should be immediately rectified. Otherwise the pavement will become irregularly worn in the vicinity of the defects, and expensive repairs will eventually be necessary.

Not infrequently weak spots develop in broken stone or gravel foundations, owing to surface water finding its way through joints in the pavement which have not been properly filled with grout. Careful observation of the joints should therefore constitute a part of the early maintenance work, and any defective joints discovered should be immediately remedied. Where the foundation is constructed of concrete, however, slight defects in the joints seldom result in any very serious damage.

If care is exercised to correct all defects which appear within the first few years of the life of a well-constructed brick pavement, the work of maintaining the pavement proper should thereafter, except for cleaning, be almost negligible for a considerable period. The shoulders and drainage structures, of course, need occasional attention, just as in the case of any other pavement, but if they are properly constructed at the start repairs will usually be very slight.

The life of a well-constructed brick pavement can not be estimated with any great degree of exactness, first, because the traffic conditions are constantly changing, and, second, because no brick pavement which has been constructed in accordance with the best modern practice has yet worn out. Such measurements as have been made

of the amounts of wear sustained by given pavements during comparatively long periods of years have not been sufficient to warrant any very definite conclusions as to the probable terms of service, though they indicate that good paving brick wear very slowly under ordinary traffic. It is evident that in order to secure the full benefit of this excellent resistance to wear the surface of the pavement must not be permitted to become uneven because of the failure of a brick here and there.

CONCLUSION.

Before concluding this discussion of brick pavements, it would seem desirable to emphasize the importance of proper engineering supervision. In the past many communities have expended large sums in efforts to improve their public highways without first having secured the services of some one competent to plan and direct the work. The results have usually been very unsatisfactory under such circumstances and have frequently served to discourage further effort. One of the mistakes most commonly observed consists in constructing some expensive type of pavement on a road where the location is faulty or the grades are impracticable. Not infrequently sharp angles in the alignment or abrupt changes in the grade, which might be easily and inexpensively remedied by an experienced engineer, are left to impede traffic throughout the life of a costly and perhaps durable pavement.

Even in constructing common earth roads it is doubtful economy to dispense with the services of a competent engineer, and if any considerable quantity of work is to be done, such services should certainly be secured. Since brick pavements are probably more expensive to construct than any other type of pavement at present used for country roads, it is all the more important that their construction should be carefully planned and well executed.

APPENDIX A.

Typical Specifications for Constructing Brick Roads.

SPECIFICATIONS [1] FOR GRADING AND SURFACING WITH BRICK THE ____________ ROAD.

Location.—The work referred to in these specifications is to be done on the ____________________ road, beginning at ________________ and extending in a __________ direction through ____________________ to ____________________, a distance of ______ miles.

Work to be done.—The contractor shall do all clearing and grubbing, make all excavations and embankments, do all shaping and surfacing, (construct all drainage structures and other appertaining structures),[2] move all obstructions in the line of the work, and, unless otherwise provided in these specifications, shall furnish all equipment, materials, and labor for the same. In short, the contractor shall construct said road in strict accordance with the plans and specifications and shall leave the work in a neat and finished condition.

PLANS AND DRAWINGS.

The plans, profiles, cross sections, and drawings on file in the office of ____________________ at ____________________ show the location, profile, details, and dimensions of the work which is to be done. The work shall be constructed according to the above-mentioned plans, profiles, cross sections, and drawings, which shall be recognized as a part of these specifications. Any variation therefrom which may be required by the exigencies of construction will in all cases be determined by the engineer. On all drawings, figured dimensions are to govern in cases of discrepancies between scale and figures.

GRADING.

Grading shall include the moving of all earth, stone, and any other material that may be encountered, all filling, borrowing, trimming, picking down, shaping, sloping, and all other work that may be necessary to bring the road and subgrade to the required grade, alignment, and cross section, the clearing out of waterways and old culverts, the excavation of all necessary drainage and outlet ditches, the grading of a proper connection with all intersecting highways, the grubbing up and clearing away of all trees, stumps, and boulders within the lines of the improvement, and the removal of any muck, soft clay, or spongy material which will not compact under the roller, so as to make a firm, unyielding subgrade.

All trees, stumps, and roots within the limit of the improvement shall be grubbed up so that no part of them shall be within six (6) inches of the surface of the ground or within eighteen (18) inches of the surface of the subgrade.

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[1] These specifications are substantially those prepared in the fall of 1913 by the Office of Public Roads for a project of considerable magnitude.

[2] The clause in parentheses should be omitted if plans and specifications for drainage structures are not included.

Embankments shall be formed of good, sound earth and carried up full width. The earth shall be deposited in layers not more than one (1) foot in thickness, and each layer shall be rolled until thoroughly compacted with a roller weighing not less than ten (10) tons. All existing slopes and surfaces of embankments shall be plowed or scarified where additional fill is to be made, in order that the old and new material may bond together. When sufficient material is not available within the fence lines to complete the embankments, suitable borrow pits, from which the contractor must obtain the necessary material, will be designated by the engineer. If there is more material taken from the cuts than is required to construct the embankments as shown on the plans, the excess material shall be used in uniformly widening the embankments or shall be deposited where the engineer may direct. Where embankments are formed of stone the material shall be carefully placed, so that all large stones shall be well distributed and the interstices shall be completely filled with small stone, earth, sand, or gravel, so as to form a solid embankment.

During the work of grading, the sides of the road shall be kept lower than the center and the surface maintained in condition for adequate drainage.

The grading of any portion of the road shall be complete before any surfacing material is placed on that portion; and where the plans do not call for any substantial change in the grade of any existing section of the road the surface shall be completely scarified to a depth of three (3) inches or more before the subgrade is prepared.

SUBGRADE.

The subgrade, or that portion of the road upon which the base for the brick roadway is to be laid, shall consist of good, sound earth brought to the proper elevation, alignment, and cross section, and shall be rolled until firm and hard. The rolling shall be done with a roller of the macadam type, weighing not less than ten (10) tons and not more than fifteen (15) tons. Should earth be encountered which will not compact by rolling, so as to be firm and hard, it shall be removed and suitable material put in its place, and that portion of the subgrade shall be again rolled. When the rolling is completed the surface of the subgrade shall conform to the cross section shown on the plans, and shall have the proper elevation and alignment, and shall be so maintained until the concrete base is in place.

MATERIALS.

Cement.—The cement for use in this work shall meet the requirements of the United States Government specifications for Portland cement as published in Circular No. 33, United States Bureau of Standards, issued May 1, 1912.

All cement shall be held at least ten (10) days after sampling before it is used in any part of the work. If the cement satisfactorily passes all tests that may be made within that time, it may be used, and the twenty-eight (28) day test will not be insisted upon; but if it should fail to pass satisfactorily any test made within that time, then the cement shall not be used until it has satisfactorily passed all tests, including the twenty-eight (28) day test. All cement shall be delivered on the work in cloth or paper bags, containing ninety-four (94) pounds, net weight, and this amount of cement shall be considered as having a volume of one (1) cubic foot. In order to allow ample time for inspecting and testing, the cement shall be stored in a suitable weather-tight building, having the floor blocked or raised from the ground, and shall be so stored as to permit of easy access for inspection, and so that each carload shipment may be readily identified.

Sand.—The sand for use as fine aggregate in all concrete or dry mortar shall be composed of particles of hard, durable stone and not more than three (3) per cent, by weight, of clay or silt. No clay, however, will be permitted if it occurs as a coating on the sand grains. The grains shall be of such sizes that all will pass a one-fourth (¼) inch mesh screen, that not more than twenty (20) per cent will pass a No. 50 sieve, and that not more than sixty (60) per cent nor less than twenty (20) per cent will be retained on a No. 20 sieve. The sand shall be of such quality that a mortar made in the proportion of one (1) part of cement to three (3) parts of the sand, according to standard methods, when tested at any age not exceeding twenty-eight (28) days, will have a tensile strength of at least one hundred (100) per cent of that developed in mortar of the same proportions made of the same cement and standard Ottawa sand. The cement used in these tests shall be from an accepted shipment of that proposed for use with the sand.

The sand for sand bedding shall be composed of particles of hard, durable stone and not more than five (5) per cent, by weight, of clay, loam, or silt. The sizes of the grains shall be such that all will pass a one-fourth (¼) inch mesh screen and not more than fifty (50) per cent will pass a No. 30 sieve. Stone screenings will not be accepted for use in the sand bedding.

The sand for the grout filler shall be composed of quartz grains and not more than one (1) per cent, by weight, of clay or silt. The grains shall be of such size that all will pass a No. 20 sieve and that not more than forty (40) per cent will pass a No. 50 sieve. The sand shall be of such quality that a mortar made in the proportion of one (1) part of cement to three (3) parts of the sand, according to standard methods, when tested at any age not exceeding twenty-eight (28) days, will have a tensile strength of not less than seventy-five (75) per cent of that developed in mortar of the same proportions made of the same cement and standard Ottawa sand. The cement used in these tests shall be from an accepted shipment of that proposed for use with the sand.

Gravel.—The gravel for use in the concrete base shall be composed of hard, sound, durable particles of stone and not more than three (3) per cent, by weight, of clay or silt. No clay, however, will be permitted if it occurs as a coating on the particles of stone or as lumps more than one (1) inch in diameter. The particles of stone shall be graded in size between those retained on a screen having circular openings one-fourth (¼) inch in diameter, or a one-fourth (¼) inch mesh screen, and those passing a screen having circular openings two (2) inches in diameter. Not more than seventy-five (75) per cent of the particles shall pass and not more than seventy-five (75) per cent shall be retained on a screen having circular openings three-fourths (¾) inch in diameter.

The gravel for use in the concrete curbs shall be composed of hard, sound, durable particles of stone, thoroughly clean and graded in size between those retained on a screen having circular openings one-fourth (¼) inch in diameter, or a one-fourth (¼) inch mesh screen, and those passing a screen having circular openings one (1) inch in diameter. Not less than forty (40) per cent shall be retained on and not less than twenty (20) per cent shall pass a one-half (½) inch mesh screen.

Crushed stone.—The crushed stone for use in the concrete base shall be clean, sound, and durable, and shall be composed of all that part of the product of the crusher which is retained on a screen having circular openings one-fourth (¼) inch in diameter, or a one-fourth (¼) inch mesh screen, and which passes a screen having circular openings two (2) inches in diameter. A sample of the stone, when subjected to the physical tests as described in the United States

Department of Agriculture Bulletin No. 347, shall satisfactorily meet the following requirements:

Hardness not less than ten (10), toughness not less than five (5), and per cent of wear not more than twelve (12).[1]

The crushed stone for use in the concrete curb shall be clean, sound, and durable, and shall be composed of all that part of the product of the crusher which is retained on a screen having circular openings one-fourth (¼) inch in diameter, or a one-fourth (¼) inch mesh screen, and which passes a screen having circular openings one and one-fourth (1¼) inches in diameter. A sample of the stone, when subjected to the physical tests as described in the United States Department of Agriculture Bulletin No. 347, shall satisfactorily meet the following requirements:

Hardness not less than twelve (12), toughness not less than six (6), and per cent of wear not more than ten (10).[1]

Slag.—The slag for use in the concrete base shall be steel-furnace slag, broken to such sizes that all of the particles will pass a screen having circular openings two (2) inches in diameter and will be retained on a screen having circular openings one-fourth (¼) inch in diameter, or a one-fourth (¼) inch mesh screen. Not more than seventy-five (75) per cent of the particles shall pass and not more than seventy-five (75) per cent shall be retained on a screen having circular openings three-fourths (¾) inch in diameter.

The material shall be reasonably uniform in character, and a sample, when subjected to the physical tests, as described in United States Department of Agriculture Bulletin No. 347, shall satisfactorily meet the following requirements:

Specific gravity not less than two and one-tenth (2.1), hardness not less than fifteen (15), toughness not less than five (5), and per cent of wear not more than fifteen (15).

Water.—The water used in the mixing of concrete or grout shall be free from oil, acid, alkali, or vegetable matter, and fairly free from clay or silt.

Brick.—The brick shall be standard wire-cut lug or re-pressed paving block. The standard size of brick shall be three and one-half (3½) inches in width, four (4) inches in depth, and eight and one-half (8½) inches in length. The brick shall not vary from these dimensions more than one-eighth (⅛) inch in width and depth and not more than one-half (½) inch in length, and in brick of the same shipment the maximum width or depth shall not vary from the minimum width or depth more than one-eighth (⅛) inch. All brick must be thoroughly annealed, regular in size and shape, and evenly burned. When broken they shall show a dense, stonelike body, free from lime, air pockets, cracks, and pronounced laminations. No surface of any brick shall have kiln marks more than three-sixteenths (3/16) inch in depth or cracks more than three-eighths (⅜) inch in depth, and the wearing surface of the brick shall not have kiln marks more than one-sixteenth (1/16) inch in depth and shall be free from cracks. The brick shall have not less than four (4) and not more than six (6) lugs, all on one side of the brick, such that when the brick are properly laid in place in the pavement the joints between them will be not less than one-eighth (⅛) nor more than one-fourth (¼) inch in width. The name or trade-mark of the manufacturer, if shown on the brick, must be recessed and not raised. If the edges of the brick are rounded, the radius shall not exceed one-eighth (⅛) inch.

The brick must not be chipped in such a manner that the wearing surface is not intact or that the lower or bearing surface is reduced in area more

[1] The values given for hardness, toughness, and per cent of wear are intended to exclude unsatisfactory stone, but in communities where better stone is readily available the requirements should be made more rigid.

than ten (10) per cent; but chipped brick, if otherwise satisfactory, may be used in obtaining the half brick for breaking courses and the necessary pieces of brick for closures. The brick shall not be salt glazed or otherwise artificially glazed. Not less than five (5) samples of ten (10) brick each will be selected from each kiln or shipment and subjected to the rattler test recommended to the American Society for Testing Materials by its subcommittee on paving brick; one sample from what appears to be the softest brick, which shall not lose of its weight more than twenty-four (24) per cent; one sample from what appears to be the hardest brick, which shall not lose of its weight less than sixteen (16) per cent or more than twenty-four (24) per cent; and three samples representing an average of the kiln or shipment, which shall not lose of their weight more than twenty-two (22) per cent: *Provided, however,* That if the softest brick lose less than twenty-four (24) per cent, the permissible minimum loss of the hardest brick will be reduced a like amount. If the kiln or shipment of brick should fail to meet the above requirements—and it is fair to assume that it would meet them if not more than ten (10) per cent were culled—then the contractor may, at his option, regrade the brick. When the regrading is complete the kiln or shipment will be resampled and retested as under the original conditions, and if it fails to meet any of the above requirements it will be finally and definitely rejected. Sampling will be done at the factory prior to shipment or from cars when placed on siding at destination, and brick satisfactorily passing the rattler test will not be rejected as a whole, but will be subject to such culling as may be necessary to meet all of the above requirements. The brick shall be carefully unloaded from cars and wagons by hand and neatly piled along the work in such manner that they will be clean and in proper condition to be laid in the pavement when desired.

Bituminous filler for expansion cushion.—The bituminous filler for the expansion cushion between the brick pavement and the curb shall be a blown-oil asphalt. It shall be soluble in chemically pure carbon disulphide to at least ninety-nine (99) per cent, and when tested by the cube method, as described in United States Department of Agriculture Bulletin No. 314, its melting point shall not be less than ninety (90) degrees centigrade and not more than one hundred and ten (110) degrees centigrade. The penetration at zero (0) degrees centigrade of a No. 2 needle acting one (1) minute under a weight of two hundred (200) grams shall be not less than two (2) millimeters. The penetration at forty-six (46) degrees centigrade of a No. 2 needle acting five (5) seconds under a weight of fifty (50) grams shall not exceed ten (10) millimeters.

CONSTRUCTION.

Concrete base.—Upon the subgrade prepared as herein specified shall be laid a concrete base of the width and thickness shown on the plans. The subgrade shall be wet but not muddy when the concrete is placed upon it. The concrete shall be composed of the following materials, by volume: One (1) part of cement, three (3) parts of sand, and five (5) parts of gravel, crushed stone, or crushed slag, and sufficient water to form a quaky mass, and shall be thoroughly mixed in a machine mixer of the batch type so constructed and operated that the thorough mixing of the materials will be assured. The concrete shall be so delivered to its place on the subgrade as not to cause or permit any separation of the materials. Wheelbarrows or other devices used for measuring the materials shall be of uniform capacity. The concrete shall be deposited in place immediately after it is mixed and shall be well compacted as fast as it is placed. The top surface shall be smoothed by troweling with

shovels or by some other means approved by the engineer, and when completed shall not vary more than one-half (½) inch from the proper shape and grade, as shown on the plans and profiles. The concrete base shall be kept wet by sprinkling with water during the first four (4) days after it is laid. No hauling over it or rolling or tamping of brick upon it will be permitted for seven (7) days after it is placed, and during this time it shall be properly protected from injury. Concrete shall not be mixed when the temperature of any of the materials is less than thirty-five (35) degrees Fahrenheit. Concrete shall not be used after it has begun to show evidence of setting, and no concrete which has once set shall be used as material for mixing a new batch.

Curbs.—Concrete curbs shall be built on the base as shown on the plans. The concrete shall be composed of the following materials, by volume: One (1) part of cement, one and one-half (1½) parts of sand, three (3) parts of gravel or crushed stone, and water. The materials shall be thoroughly mixed in a machine mixer of the batch type or by hand. If the mixing is done by hand, it shall be done upon a water-tight platform with raised edges, in such manner as to insure thorough mixing of the materials and to meet the approval of the engineer. The concrete for the curb shall be placed upon the base before the concrete of either the curb or the base has taken its initial set, and care shall be taken, such as roughening the concrete of the base and tamping the concrete of the curb, to insure that the curb will be firmly bonded to the base. The concrete shall be well tamped and spaded along the forms, so that when they are removed there will be no open and porous places on the sides of the curb. The top surface of the curb shall be floated or troweled to a smooth finish. The forms for the curb shall be smooth, clean, free from warp, and of sufficient strength to resist springing out of shape. They shall be well staked and braced, and the top edges shall be at the same height and set true to line. To protect the curb from drying out too rapidly it shall, within twelve (12) hours after it is placed, be covered with gunny cloth, which shall be kept wet for five (5) days.

Sand bedding.[1]—Upon the base shall be spread a bedding of sand such that it will have a uniform depth of approximately one and one-half (1½) inches when compacted. The base shall be thoroughly clean at the time the bedding is spread. The bedding shall be carefully shaped to a true cross section of the roadway by means of a template having a steel-faced edge, and so fitted as to be readily drawn on the curb. After the bedding is so shaped, it shall be rolled with a hand roller until the material composing it is well compacted. The depressions formed by rolling shall be filled and the surface of the bedding trued up with the template and rolled again. This operation of filling depressions, truing up with template, and rolling shall be repeated as often as is necessary to secure a well-compacted bedding true to grade and to the required cross section. The rolling shall be done with a hand roller not less than twenty-four (24) inches in diameter, not less than twenty-four (24) inches in width, and weighing not less than ten (10) pounds per inch of width.

Laying brick.—Upon the bedding, prepared as above described, the brick shall be laid on edge from curb to curb in straight courses at right angles to the curb, with the lug sides all in the same direction. The brick shall be laid so that the lugs of the brick in one course will touch the brick in the adjoining

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[1] If a dry-mortar bedding is to be used substitute the following:

Dry-mortar bedding.—Upon the base shall be spread a dry-mortar bedding composed of 1 part of Portland cement to 5 parts of sand thoroughly mixed. The dry mortar shall be spread in such quantity as to give an average depth of approximately 1 inch when compacted. The base shall be thoroughly clean at the time the bedding is spread, etc.

course, and the joints between the ends of the brick shall not exceed one-eighth ($\frac{1}{8}$) inch in width. Joints shall be broken by starting each alternate course with a half brick. Nothing but whole brick shall be used, excepting the half brick for starting alternate courses and pieces of brick for closures, and no piece of brick less than two (2) inches in length shall be used for making a closure. The cutting and trimming of brick shall be done by experienced men, and proper care shall be taken not to check or fracture the part to be used, and the ends of the part used shall be square with its top and sides.

The brick shall be carried to the bricklayers on pallets or in clamps and not wheeled in barrows. The bricklayers laying the brick shall stand on the brick already laid and shall not in any manner disturb the bedding. No heavy driving will be permitted to straighten courses, and in making closures the pieces of brick shall be so cut that they may be laid in place without driving. Brick shall be laid with the best edge up. Batting for closures shall progress with the laying.

After the brick are laid they will be carefully inspected, and all those which are soft, cracked, glazed, spalled, overburned, or otherwise imperfect will be marked by the inspector. The contractor shall at once remove such brick from the pavement with flat-nosed tongs, without disturbing the bedding, and shall replace them with approved brick. Kiln-marked and slightly chipped brick, if not otherwise defective, may be turned over and, if the reverse edge is smooth, may remain in the pavement.

If more than one kind of brick or the brick from more than one plant is furnished for the work, each particular kind or make shall be laid in a separate section.

Rolling brick.—After the brick have been laid and after all objectionable brick have been removed from the pavement they shall be brought to a true surface by means of rolling. The rolling shall be done with a motor or steam tandem roller weighing not less than three (3) and not more than five (5) tons. The pavement shall be rolled in longitudinal and diagonal directions. The longitudinal rolling shall begin at the curbs and progress toward the center of the pavement. The pavement shall then be thoroughly rolled diagonally at an angle of forty-five (45) degrees with the curb. When this rolling has been completed the brick will again be inspected, and all that are broken or damaged shall be removed from the pavement and replaced with approved brick. If necessary to secure a uniform surface the brick shall then be again rolled, the roller moving diagonally across the pavement at right angles to the first diagonal rolling. To prevent the brick from being left careened the roller shall in all cases cover exactly the same area in making its backward trip as was covered in its forward trip, and shall proceed at a very slow rate of speed until the entire pavement has received the first rolling. In no event shall the rolling be done when the bedding is in a condition such that the sand or dry mortar will flow up into the joints more than three-eighths ($\frac{3}{8}$) inch.

Filling the joints.—After the brick have been rolled as above specified the joints between them shall be filled with a grout containing equal parts of cement and sand. The grout shall be mixed in a mechanical batch mixer or by hand in batches containing not more than one sack of cement. Hand mixing shall be done in a box about five (5) feet long, thirty (30) inches wide, and fourteen (14) inches deep, resting on legs of different lengths, so that the mixture will readily flow to the lowest corner of the box. The sand and cement shall be thoroughly mixed dry. Sufficient clean water shall then be admixed to produce a grout of a consistency about equal to that of ordinary cream for the first application and of a slightly thicker consistency for subsequent applications. From the time the water is added to the mixture until all of the

grout is removed from the box, the mixture must be constantly well stirred with mortar hoes. The grout shall be removed from the box with scoop shovels and applied to the brick in front of men supplied with push brooms, who shall rapidly sweep it lengthwise of the brick into the joints until the joints are practically filled. After the first application has been made and the grout has settled into the joints, and before initial set has taken place, the unfilled portion of the joints shall be filled with the thicker grout, and, if necessary, refilled until the joints remain full to the top. After this has been done the pavement shall be finished to a smooth surface, free from any surplus grout, with a squeegee, which shall be worked over the brick at an angle of about forty-five (45) degrees with the curb. The pavement shall have been thoroughly sprinkled before the first application of grout is made, and shall be kept moist by means of gentle sprinkling until the grout is spread. The top surface, sides, and ends of the brick shall be thoroughly clean at the time the work of filling the joints is done.

Immediately after the grout has taken its initial set the pavement shall be covered with a one (1) inch layer of sand or earth. This layer, immediately after it is placed on the pavement, shall be thoroughly wet by sprinkling and shall be kept wet by sprinkling for at least the five (5) following days. It shall remain on the pavement for at least ten (10) days and shall be removed before traffic is permitted upon the pavement. During this period of ten (10) days or longer, as the engineer may require on account of weather conditions, no traffic shall be allowed upon and no materials shall be placed upon the pavement.

Expansion cushion.[1]—An expansion cushion four (4) inches in depth and of the thickness indicated on the plans shall be constructed along each curb as follows: Suitable provision for the cushion shall be made at the time the brick are laid by setting boards of the proper width and thickness on edge in proper position along the curb. After the brick have been laid, rolled, and grouted, and the grout has well set, the boards shall be carefully removed, so as not to damage the curb or the brick pavement, and the spaces which they occupied shall be filled with blown-oil asphalt heated to a temperature of not less than three hundred (300) degrees Fahrenheit and not more than four hundred (400) degrees Fahrenheit.

ALTERNATE SPECIFICATIONS.

SEPARATE CONCRETE CURBS.

Where the plans call for concrete curbs separate from the foundation they shall be constructed before the subgrade is finally completed and shall have the cross section shown on the plans. Such curbs shall be constructed in sections not less than six (6) feet and not more than twelve (12) feet in length and shall be true to grade and alignment.

The specification already given for concrete curbs constructed in combination with the foundation shall also apply to curbs constructed separate from the foundation as regards proportioning, mixing, and placing the concrete, constructing the forms, and all other features of construction which are not covered on the plans or in this specification.

STONE CURBS.

Where stone curbs are required, they shall be hauled and set before the subgrade is finally completed. The curbs shall be set true to line and grade

[1] Instead of making a poured joint, as above described, the cushion may be constructed of some of the specially prepared expansion-joint materials, subject to the approval of the engineer as to the material and method of construction.

and shall be securely bedded in broken stone, gravel, or firm earth. In preparing the trenches for the curbs great care shall be exercised to see that the material upon which the curb is to be set is well compacted, firm, and hard.

Stone curbing shall be quarried from hard, tough, homogeneous stone. The individual blocks shall have the cross section shown on the plans and shall be not less than four (4) feet in length. Each block shall be free from seams and all other imperfections and shall be neatly dressed and finished on all exposed faces.

APPENDIX B.

Method for Inspecting and Testing Paving Brick.[1]

The quality and acceptability of paving brick, in the absence of other special tests mutually agreed upon in advance by the seller on the one side and the buyer on the other side, shall be determined by the following procedure, viz:

(1) *The rattler test*, for the purpose of determining whether the material as a whole possesses to a sufficient degree, strength, toughness, and hardness;

(2) *Visual inspection*, for the purpose of determining whether the physical properties of the material as to dimensions, accuracy and uniformity of shape and color are in general satisfactory, and for the purpose of culling out from the shipment individually imperfect or unsatisfactory brick.

The acceptance of paving brick as satisfactorily meeting one of these tests shall not be construed as in any way waiving the other.

SECTION 1.—THE RATTLER TEST.

THE SELECTION OF SAMPLES FOR TEST.

ITEM 1. *Place of sampling.*—In general where a shipment of brick involving a quantity of less than 100,000 is under consideration, the sampling may be done either at the brick factory prior to shipment, or on cars at their destination, or on the street when delivered ready for use. When the quantity under consideration exceeds 100,000, the sampling shall be done at the factory prior to shipment. Brick accepted as the result of tests prior to shipment shall not be liable to subsequent rejection as a whole, but are subject to such culling as is provided for under Section II (Visual Inspection).

ITEM 2. *Method of selecting samples.*—In general the buyer shall select his own samples from the material which the seller promises to furnish. The seller shall have the right to be present during the selection of a sample. The sampler shall endeavor, to the best of his judgment, to select brick representing the average of the lot. No samples shall include brick which would be rejected by visual inspection as provided in Section II, except that where controversy arises, whole tests may be selected to determine the admissibility of certain types or portions of the lot having a characteristic appearance in common. In cases where prolonged controversy occurs between buyer and seller, and samples selected by each party fail to show reasonable concurrence, then both parties shall unite in the selection of a disinterested person to select the samples, and both parties shall be bound by the results of samples thus selected.

ITEM 3. *Number of samples per lot.*—In general one sample of 10 brick shall be tested for every 10,000 brick contained in the lot under consideration,

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[1] Recommended by subcommittee on paving brick of the American Society for Testing Materials.

but where the total quantity exceeds 100,000, the number of samples tested may be fewer than 1 per 10,000, provided that they shall be distributed as uniformly as practicable over the entire lot.

ITEM 4. *Shipment of samples.*—Samples which must be transported long distances by freight or express must be carefully put up in packages holding not more than 12 brick each. When more than six brick are shipped in one package, it must be so arranged as to carry two parallel rows of brick side by side, and these rows must be separated by a partition. In event of some of the brick being cracked or broken in transit, the sample shall be disqualified if there are not remaining 10 sound undamaged brick.

ITEM 5. *Storage and care of samples.*—Samples must be carefully handled to avoid breakage or injury. They must be kept dry so far as practicable. If wet when received, or known to have been immersed or subjected to recent prolonged wetting, they shall be dried for at least six hours in a temperature of 100° F. before testing.

THE CONSTRUCTION OF THE RATTLER.

ITEM 6. The machine shall be of good mechanical construction, self-contained, and shall conform to the following details of materials and dimensions, and shall consist of barrel, frame, and driving mechanism as herein described. Accompanying these specifications is a complete drawing (Pl. XII) of a rattler which will meet the requirements, and to which reference should be made.

ITEM 7. *The barrel.*—The barrel of the machine shall be made up of the heads and head liners and staves and stave liners.

The heads may be cast in one piece with the trunnions, which shall be $2\frac{1}{2}$ inches in diameter and shall have a bearing 6 inches in length, or they may be cast with heavy hubs, which shall be bored out for $2\frac{7}{16}$-inch shafts, and shall be keyseated for two keys, each $\frac{1}{2}$ inch by $\frac{3}{8}$ inch and spaced 90° apart. The shaft shall be a snug fit, and when keyed shall be entirely free from lost motion. The distance from the end of the shaft or trunnion to the inside face of the head shall be $15\frac{3}{8}$ inches in the head for the driving end of the rattler and $11\frac{3}{8}$ inches long for the other head, and the distance from the face of the hubs to the inside face of the heads shall be $5\frac{1}{8}$ inches.

The heads shall be not less than $\frac{3}{4}$ inch nor more than $\frac{7}{8}$ inch thick. In outline each head shall be a regular 14-sided polygon inscribed in a circle $28\frac{3}{8}$ inches in diameter. Each head shall be provided with flanges not less than $\frac{3}{4}$ inch thick and extending outward $2\frac{1}{2}$ inches from the inside face of the head to afford a means of fastening the staves. The surface of the flanges of the head must be smooth and must give a true and uniform bearing for the staves. To secure the desired true and uniform bearing the surfaces of the flanges of the head must be either ground or machined. The flanges shall be slotted on the outer edge so as to provide for two $\frac{3}{4}$-inch bolts at each end of each stave, said slots to be $\frac{13}{16}$ inch wide and $2\frac{3}{4}$ inches center to center. Each slot shall be provided with a recess for the bolt head, which shall act to prevent the turning of the same. Between each two slots there shall be a brace $\frac{3}{8}$ inch thick extending down the outward side of the head not less than 2 inches.

There shall be for each head a cast-iron head liner 1 inch in thickness and conforming to the outline of the head, but inscribed in a circle $28\frac{1}{8}$ inches in diameter. This head liner shall be fastened to the head by seven $\frac{5}{8}$-inch cap screws through the head from the outside. Whenever these head liners become worn down $\frac{1}{2}$ inch below their initial surface level at any point of their surface they must be replaced with new ones. The metal of these head liners shall be

hard machinery iron and should contain not less than 1 per cent of combined carbon.

The staves shall be made of 6-inch medium steel structural channels 27¼ inches long and weighing 15.5 pounds per linear foot. The staves shall have two holes 13/16 inch in diameter, drilled in each end, the center line of the holes being 1 inch from the end and 1⅝ inches either way from the longitudinal center line. The spaces between the staves shall be as uniform as practicable, but must not exceed 5/16 inch.

The interior or flat side of each stave shall be protected by a liner ⅝ inch thick by 5½ inches wide by 19¾ inches long. The liner shall consist of medium steel plate and shall be riveted to the channel by three ½-inch rivets, one of which shall be on the center line both ways and the other two on the longitudinal center line and spaced 7 inches from the center each way. The rivet holes shall be countersunk on the face of the liner and the rivets shall be driven hot and chipped off flush with the surface of the liners. These liners shall be inspected from time to time, and if found loose shall be at once re-riveted.

Any test at the expiration of which a stave liner is found detached from the stave or seriously out of position shall be rejected. When a new rattler in which a complete set of new staves is furnished is first put into operation, it shall be charged with 400 pounds of shot of the same sizes, and in the same proportions as provided in Item 9, and shall then be run for 18,000 revolutions at the usual prescribed rate of speed. The shot shall then be removed and a standard shot charge inserted, after which the rattler may be charged with brick for a test.

No stave shall be used for more than 70 consecutive tests without renewing its lining. Two of the 14 staves shall be removed and relined at a time, in such a way that of each pair one falls upon one side of the barrel and the other upon the opposite side, and also so that the staves changed shall be consecutive, but not contiguous; for example, 1 and 8, 3 and 10, 5 and 12, 7 and 14, 2 and 9, 4 and 11, 6 and 13, etc., to the end that the interior of the barrel at all times shall present the same relative condition of repair. The changes in the staves should be made at the time when the shot charges are being corrected, and the record must show the number of charges run since the last pair of newly lined staves was placed in position.

The staves when bolted to the heads shall form a barrel 20 inches long, inside measurement, between head liners. The liners of the staves must be so placed as to drop between the head liners. The staves shall be bolted tightly to the heads by four ¾-inch bolts, and each bolt shall be provided with a lock nut, and shall be inspected at not less frequent intervals than every fifth test, and all nuts shall be kept tight. A record shall be made after each inspection showing in what condition the bolts were found.

ITEM. 8. *The frame and driving mechanism.*—The barrel shall be mounted on a cast-iron frame of sufficient strength and rigidity to support it without undue vibration. It shall rest on a rigid foundation with or without the interposition of wooden plates and shall be fastened thereto by bolts at not less than four points.

It shall be driven by gearing whose ratio of driver to driven is not less than one to four. The countershaft upon which the driving pinion is mounted shall not be less than 1 15/16 inches in diameter, with bearings not less than 6 inches in length. If a belt drive is used, the pulley shall not be less than 18 inches in diameter and 6½ inches in face. A belt at least 6 inches in width, properly adjusted to avoid unnecessary slipping, should be used.

ITEM 9. *The abrasive charge.*—The abrasive charge shall consist of cast-iron spheres of two sizes. When new, the larger spheres shall be 3.75 inches in diameter and shall weigh approximately 7.5 pounds (3.40 kilos) each. Ten spheres of this size shall be used.

These shall be weighed separately after each 10 tests, and if the weight of any large sphere falls to 7 pounds (3.175 kilos), it shall be discarded and a new one substituted, provided, however, that all of the large spheres shall not be discarded and substituted by new ones at any single time, and that so far as possible the large spheres shall compose a graduated series in various stages of wear.

When new, the smaller sized spheres shall be 1.875 inches in diameter and shall weigh approximately 0.95 pound (0.43 kilo) each. In general the number of small spheres in a charge shall not fall below 245 nor exceed 260. The collective weight of the large and small spheres shall be as nearly as possible 300 pounds. No small sphere shall be retained in use after it has been worn down so that it will pass a circular hole 1.75 inches in diameter, drilled in an iron plate ¼ inch in thickness, or weigh less than 0.75 pound (0.34 kilo). Further, the small spheres shall be tested by passing them over the above plate, or shall be weighed after every 10 tests, and any which pass through the plate or fall below the specified weight shall be replaced by new spheres; and provided further, that all of the small spheres shall not be rejected and replaced by new ones at any one time, and that so far as possible the small spheres shall compose a graduated series in various stages of wear. At any time that any sphere is found to be broken or defective it shall at once be replaced.

The iron composing these spheres shall have a chemical composition within the following limits:

Combined carbon, not less than 2.50 per cent.
Graphitic carbon, not more than 0.25 per cent.
Silicon, not more than 1 per cent.
Manganese, not more than 0.50 per cent.
Phosphorus, not more than 0.25 per cent.
Sulphur, not more than 0.08 per cent.

For each new batch of spheres used the chemical analysis must be furnished by the maker or be obtained by the user before introducing into the charge, and unless the analysis meets the above specifications the batch of spheres shall be rejected.

THE OPERATION OF THE TEST.

ITEM 10. *The brick charge.*—The number of brick per test shall be 10 for all bricks of so-called "block size," whose dimensions fall between from 8 to 9 inches in length, 3 to 3¾ inches in breadth, and 3¾ inches to 4¼ inches in thickness.[1] No brick should be selected as a part of a regular test that would be rejected by any other requirements of the specifications under which the purchase is made.

ITEM 11. *Speed and duration of revolution.*—The rattler shall be rotated at a uniform rate of not less than 29½ nor more than 30½ revolutions per minute, and 1,800 revolutions shall constitute the test. A counting machine shall be attached to the rattler for counting the revolutions. A margin of not to exceed 10 revolutions will be allowed for stopping. Only one start and stop per test is generally acceptable. If from accidental causes the rattler is stopped and started more than once during a test and the loss exceeds the maximum per-

[1] Where brick of larger or smaller sizes than the dimensions given above for blocks are to be tested, the same number of bricks per charge should be used, but allowance for the difference in size should be made in setting the limits for average and maximum rattler loss.

missible under the specifications, the test shall be disqualified and another made.

ITEM 12. *The scales.*—The scales must have a capacity of not less than 300 pounds and must be sensitive to one-half of an ounce and must be tested by a standard test weight at intervals of not less than every 10 tests.

ITEM 13. *The results.*—The loss shall be calculated in percentage of the initial weight of the brick composing the charge. In weighing the rattled brick any piece weighing less than 1 pound shall be rejected.

ITEM 14. *The records.*—A complete and continuous record shall be kept of the operation of all rattlers working under these specifications. This record shall contain the following data concerning each test made:

1. The name of the person, firm, or corporation furnishing each sample tested.
2. The name of the maker of the brick represented in each sample tested.
3. The name of the street or contract which the sample represented.
4. The brands or marks upon the bricks by which they were identified.
5. The number of bricks furnished.
6. The date on which they were received for test.
7. The date on which they were tested.
8. The drying treatment given before testing, if any.
9. The length, breadth, and thickness of the bricks.
10. The collective weight of the 10 large spherical shot used in making the test at the time of their last standardization.
11. The number and collective weight of the small spherical shot used in making the test at the time of their last standardization.
12. The total weight of the shot charge after its last standardization.
13. Certificate of the operator that he examined the condition of the machine as to staves, liners, and any other parts affecting the barrel and found them right at the beginning of the test.
14. Certificate of the operator of the number of charges tested since the last standardization of shot charge.
15. The time of the beginning and ending of each test and the number of revolutions made by the barrel during the test as shown by the indicator.
16. Certificate of the operator as to number of stops and starts made in each test.
17. The initial collective weight of the 10 brick composing the charge and their collective weight after rattling.
18. The loss calculated in per cents of the initial weight; and the calculation itself.
19. The number of broken brick and remarks upon the portions which were included in the final weighing.
20. General remarks upon the test and any irregularities occurring in its execution.
21. The date upon which the test was made.
22. The location of the rattler and name of the owner.
23. The certificate of the operator that the test was made under specifications of the American Society for Testing Materials and that the record is a true record.
24. The signature of the operator or person responsible for the test.
25. The serial number of the test.

In event of more than one copy of the record of any test being required, they may be furnished on separate sheets and marked duplicates, but the original record shall always be preserved intact and complete.

ACCEPTANCE AND REJECTION OF MATERIAL.

ITEM 15. *Basis of acceptance or rejection.*—Paving brick shall not be judged for acceptance or rejection by the results of individual tests, but by the average of not less than five tests. Where a lot of brick fails to meet the required average it shall be optional with the buyer whether the brick shall be definitely rejected or whether they may be regraded and a portion selected for further test as provided in item 16.

ITEM 16. *Range of fluctuation.*—Some fluctuation in the results of the rattler test, both on account of variation in the brick and in the machine used in testing, are unavoidable, and a reasonable allowance for such fluctuations should be made wherever the standard may be fixed.

In any lot of paving brick, if the loss on a test computed upon its initial weight exceeds the standard loss by more than 2 per cent, then the portion of the lot represented by that test shall at once be resampled and three more tests executed upon it, and if any of these three tests shall again exceed by more than 2 per cent the required standard, then that portion of the lot shall be rejected.

If in any lot of brick two or more tests exceed the permissible maximum, then the buyer may, at his option, reject the entire lot, even though the average of all the tests executed may be within the required limits.

ITEM 17. *Fixing of standards.*—The percentage of loss which may be taken as the standard will not be fixed in these regulations, and shall remain within the province of the contracting parties. For the information of the public the following scale of average losses is given, representing what may be expected of tests executed under the foregoing specifications:

	General average loss.	Maximum permissible loss.
	Per cent.	*Per cent.*
For brick suitable for heavy traffic	22	24
For brick suitable for medium traffic	24	26
For brick suitable for light traffic	26	28

Which of these grades should be specified in any given district and for any given purpose is a matter wholly within the province of the buyer, and should be governed by the kind and amount of traffic to be carried, and the quality of paving brick available.

ITEM 18. *Culling and retesting.*—Where under items 15 and 16 a lot or portion of a lot of brick is rejected, either by reason of failure to show a low enough average test or because of tests above the permissible maximum, the buyer may at his option permit the seller to regrade the rejected brick, separating out that portion which he considers at fault and retaining that which he considers good. When the regrading is complete the good portion shall be then resampled and retested, under the original conditions, and if it fails again either in average or in permissible maximum, then the buyer may definitely and finally reject the entire lot or portion under test.

ITEM 19. *Payment of cost of testing.*—Unless otherwise specified, the cost of testing the material as delivered or prepared for delivery, up to the prescribed number of tests for valid acceptance or rejection of the lot, shall be paid by the buyer. (See also item 23.) The cost of testing extra samples made necessary by the failure of the whole lot or any portion of it shall be paid by the seller, whether the material is finally accepted or rejected.

SECTION II.—VISUAL INSPECTION.

It shall be the right of the buyer to inspect the brick, subsequent to their delivery at the place of use, and prior to or during laying, to cull out and reject upon the following grounds:

ITEM 20. All brick which are broken in two or chipped in such a manner that neither wearing surface remains substantially intact, or that the lower or bearing surface is reduced in area by more than one-fifth. Where brick are rejected upon this ground, it shall be the duty of the purchaser to use them so far as practicable in obtaining the necessary half brick for breaking courses and making closures, instead of breaking otherwise whole and sound brick for this purpose.

ITEM 21. All brick which are cracked in such a degree as to produce defects such as defined in item 20, either from shocks received in shipment and handling or from defective conditions of manufacture, especially in drying, burning, or cooling, unless such cracks are plainly superficial and not such as to perceptibly weaken the resistance of the brick to its conditions of use.

ITEM 22. All brick which are so offsize, or so misshapen, bent, twisted, or kiln marked that they will not form a proper surface as defined by the paving specifications, or align with other brick without making joints other than those permitted in the paving specifications.

ITEM 23. All brick which are obviously too soft and too poorly vitrified to endure street wear. When any disagreement arises between buyer and seller under this item, it shall be the right of the buyer to make two or more rattler tests of the brick which he wishes to exclude, as provided in item 2, and if in either or both tests the brick fall beyond the maximum rattler losses permitted under the specifications, then all brick having the same objectionable appearance may be excluded, and the seller must pay for the cost of the test. But if under such procedure the brick which have been tested as objectionable shall pass the rattler test, both tests falling within the permitted maximum, then the buyer can not exclude the class of material represented by this test and he shall pay for the cost of the test.

ITEM 24. All bricks which differ so markedly in color from the type or average of the shipment as to make the resultant pavement checkered or disagreeably mottled in appearance. This item shall not be held to apply to the normal variations in color which may occur in the product of one plant among brick which will meet the rattler test as referred to in items 15, 16, and 17, but shall apply only to differences of color which imply differences in the material of which the brick are made, or extreme differences in manufacture.

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